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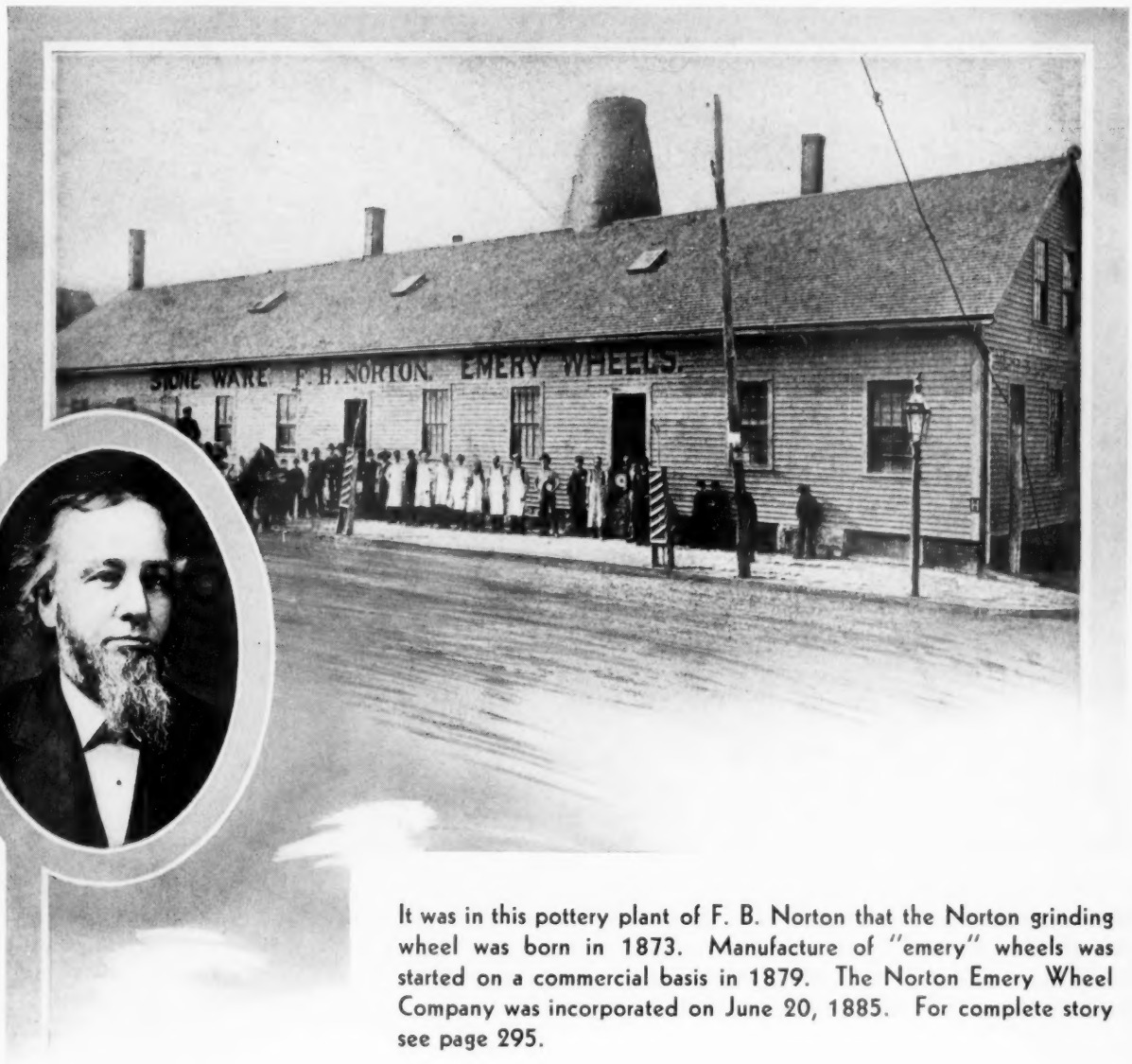
THE BULLETIN OF THE AMERICAN CERAMIC SOCIETY

THE BULLETIN

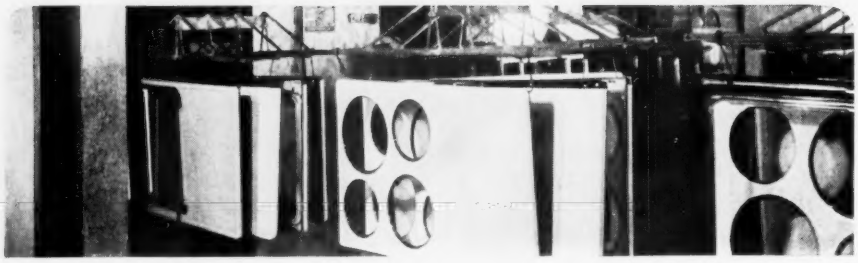
OF THE

AMERICAN CERAMIC SOCIETY

Volume 15 AUGUST, 1936 Number 8



It was in this pottery plant of F. B. Norton that the Norton grinding wheel was born in 1873. Manufacture of "emery" wheels was started on a commercial basis in 1879. The Norton Emery Wheel Company was incorporated on June 20, 1885. For complete story see page 295.



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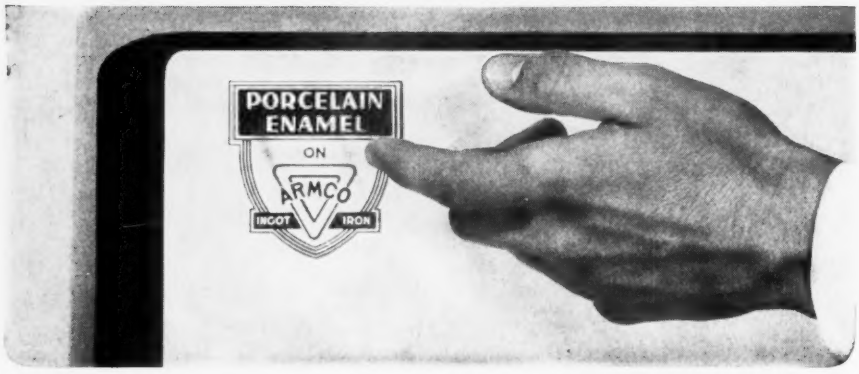

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THE BULLETIN OF THE AMERICAN CERAMIC SOCIETY

Volume 15 August, 1936 Number 8

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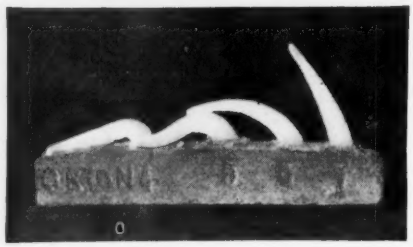

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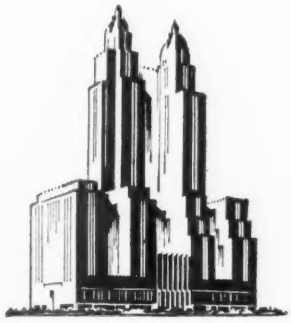

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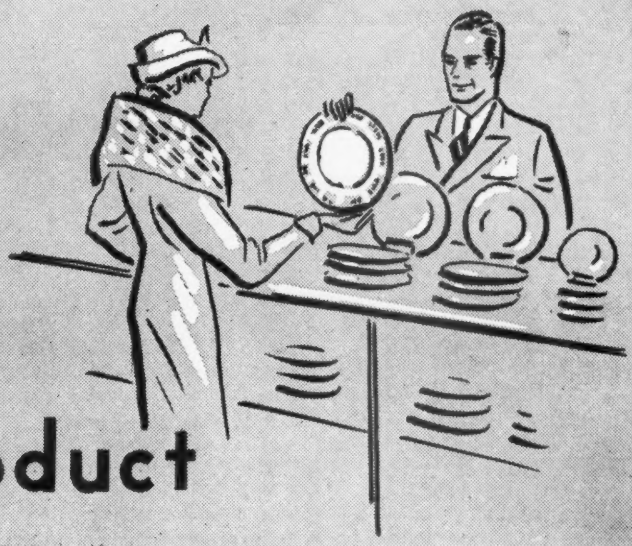

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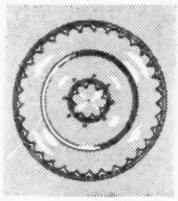

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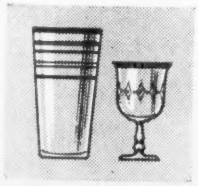

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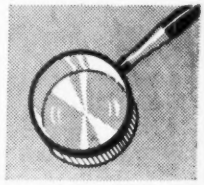

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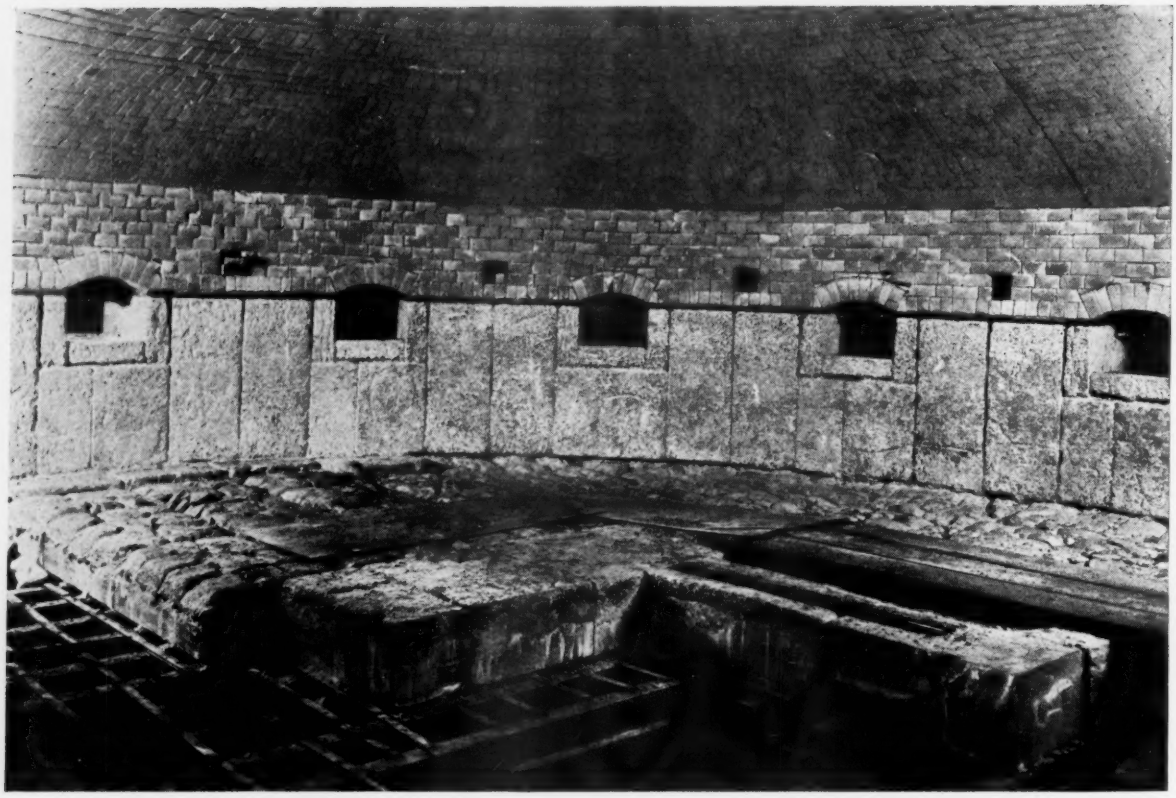

12 CORHART FURNACES HAVE REFINING ENDS 7 YEARS OLD

AMONG the numerous Corhart refining ends today, there are *twelve* in the U.S. alone *that have passed their seventh year without repairs* except for a block or two at key points. Corhart Electrocast has been on the market for only eight years.

The above photograph shows why such records are possible. It illustrates a Corhart refining end after a long pull at heavy load making clear flint glass for bottles.

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FUNDAMENTAL PROBLEMS RELATING TO THE STRENGTH OF GLASSWARE*

By F. W. Preston

Editor's Note: The following papers conclude a series on the strength of glass which was presented at the Summer Meeting of the Glass Division, September 13 to 15, 1935. The first two papers in this series were published in the July issue of *The Bulletin*.

The science of the mechanical strength of glass will be discussed, possibly from a more fundamental and less specialized angle than a discourse on electric-lamp bulbs. This Symposium deals mainly with practical experiences of testing, for our practical needs at the present time must be met by empirical procedures. It may seem therefore that the writer's attempt to consider purely scientific angles is somewhat gratuitous.

I wish to call attention first to the limitations of the Theory of Elasticity. This is a most useful branch of science and highly mathematical. It looks so profound and thorough that unfortunately those who do not understand it are unduly impressed by it. It is not generally recognized how little this theory has really succeeded in explaining or what simplifications are introduced to make mathematical symbols on which the theory can operate.

The theory of elasticity sets out to determine what stresses will be created in certain bodies, usually bodies of a simple geometrical shape, by certain forces or pressures, usually of a simple character. The first assumption is that the stresses are elastic in character, that is, they will disappear with the removal of the forces, and the strains or distortions will likewise disappear. Unfortunately, we are rarely, if ever, interested in stresses of this type. As long as an article is stressed within the elastic limit, we do not care whether it is stressed at all. The possibility of a thing being "overloaded" and "failing," that is, passing beyond the elastic limit, is the only thing that is important.

When I pour hot coffee into my china cup or porcelain mug I know from experience that the ware will not break. But when I pour coffee into a glass cup I know that, whatever the theory may be, in practice the thing is about as apt to break as not, and immediately I get the jitters. Unfortunately, the theory of elasticity has nothing to say about breakage: it is concerned only with the distribution of stress throughout a body subject to load and with the strains produced thereby. Plastic failure or brittle fracture is beyond its treatment.

Even the assumption that glass fails when an applied stress exceeds the strength of the material is not true in any general sense. As a literary effort, this may merely mean that the ware breaks when it can not stand the "gaff," but if we try to give precision to the statement by assigning a numerical value to the word "strength," we usually find that there is no figure that can be set down as the "strength" of a glass or, if there is, the stress which breaks the glass in any particular instance has little or nothing to do with this figure. In a glass of definite chemical composition and properly annealed, we can say that, whatever its shape or outward appearance, it can have only

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one refractive index for sodium light, and we can find its value. There is only one photoelastic constant, and we can find that; there is a definite liquidus temperature and course of crystallization, subject only to minor vagaries; there is a definite value of Young's modulus of elasticity and of Poisson's ratio; but there is no definite figure for "strength."

G. W. Morey has stated that all commercial glass is "grossly inhomogeneous" from the viewpoint of physical chemistry, and he has gone to much trouble to prepare homogeneous samples for his work on crystallization; but even the best of his samples are grossly inhomogeneous from a mechanical standpoint. This does not mean that they are full of "cords"; it perhaps means only that they are full of atoms. The theory of elasticity assumes that matter, such as glass, is a continuum; in reality it is a discontinuous structure made of atoms, a network with rents in it.

The theoretical strength or "cohesion" of glass is very high. In practice, the strength we find is probably not 1% of what is theoretically possible. Glass ought to support one million pounds per square inch (tension), but in practice it often fails at 4000 pounds.

The possibility that one day we may attain something like the theoretical strength is not to be dismissed lightly; temporarily, strengths not far short of it have been attained. The value of such a material as a glass, with a weight not exceeding that of aluminum, a chemical permanence exceeding that of stainless alloys, a strength exceeding the finest nickel steel, and far cheaper than any, is obviously such as would open a new era in civilization. The search for the missing strength of glass, hopeless though it may appear from past experience, must clearly continue to be one of the major objectives of the human race.

The fact that some 99% of the strength of glass is missing in practice no doubt explains why measurements of strength vary so much. A variation in the missing amount from 98.5 to 99.5% does not seem great, but the residual strength, which is what we measure, would then vary from $^1/_2$ to $1^1/_2$% of the theoretical, which is a three to one ratio; it may also be expressed as a ± 50% deviation from the average (residual) strength. Such values are obtained, and deviations of the order of ± 15 or ± 20% are usual.

In dealing with structural steel, the theory of elasticity, which is favored by engineers even in its cruder forms, is often useful for a reason which is of no particular credit to the theory itself. After structural steel passes the "yield point," it enters a plastic range. In this range the strain or distortion increases rapidly, while the stress increases, for a time, but little. This permits the highly stressed areas to pass on part of their load to other areas so that, in many cases, the stress distribution becomes more nearly what the designer hoped it would be or what the theory of elasticity indicated. This automatic simplification produced by the steel is something outside the purview of the glass worker. *His* material is not so obliging.

The plasticity of steel, when overstressed, is in a sense itself a residual property. Pure iron is extremely soft and plastic, and a single crystal of absolutely pure iron would probably be as strong as putty. The irons and steels that we actually use are strengthened in two ways, (1) by alloying them with carbon and other elements and (2) by substituting a mosaic of crystals for a single crystal. Both procedures are equivalent to making a partial *glass* of the metal. Thus by a curious perversity, we can confer on iron, which is theoretically weak, the great strength of nickel steel, while with silica glass, which is theoretically strong, we can obtain only weak specimens in practice.

Most engineering structures are too complex for adequate analysis by the theory of elasticity, and in practice we try to reduce structures to designs on which some sort of calculation is possible. Thus we try to use triangulated lattice girders or arches conforming to inverted catenaries, and we introduce weak spots, "hinges," into arches to insure that the stresses shall be what we hope they will be.

Dr. Hampton recently called the writer's attention to the fact that the theory of elasticity had not, as yet, produced any solution of many apparently simple problems. For instance, he had been unable to find any theory of the stability of a thin spherical shell subjected to uniformly distributed external hydrostatic pressure. The shrinking earth is believed to have collapsed from a sphere to a half-hearted tetrahedron, with four low spots and four high corners, and this may presumably be the natural fate of a hollow sphere subjected to external pressure, but I have nowhere found the theory of the critical collapsing pressure.

If the sphere be initially a little out of round, the

collapsing pressure is probably much lower, and an ellipsoidal shell might have very little strength. Similarly, a spherical shell with variable wall thickness might have little strength.

Eggs, as everyone knows, are quite strong endwise and weak sidewise, but we have no theory to deal with this. Submitted suddenly to increased atmospheric pressure, the sidewise weakness might be fatal.

Many objects of glass can be regarded as approximations to hollow spheres, ellipsoids, or ovoids (eggs), and they are often used under partial internal vacuum, that is, under excess external pressure. The matter is not academic, and we have as yet no assistance from the theory of elasticity. On the other hand, we have a theory of the collapse of hollow tubes, which is quite complicated, both as to the form the tube shall assume on collapsing and the effect of length of tube on the form and on the pressure required.

From these dark subjects we turn to a darker one, the mysterious influence of the time factor on residual strength. There is nothing whatever in the theory of elasticity which envisages the possibility that glass may fail in an hour under a stress it has stood for half an hour. There seems to be a tendency to apply the term "fatigue" to this failure under prolonged loading. The term is a natural one, but it does not agree entirely with what the engineer usually understands by fatigue. He understands by the term, not that steel gets tired of passively supporting a steady load, but that it can be wearied by making it do something, such as vibrating. Thus a spring under alternate compression and relaxation is found to give out at lower stresses than a spring under constant maximum load. Before we apply the term "fatigue" to the phenomenon in glass, we ought to be sure that it is a similar phenomenon.

As a matter of form, I should object to a statement that "the compressive strength of glass is much higher than its tensile strength, possibly seventeen times as great." The term "compressive strength" is meaningless, for all we can measure in a compression test is not a property of the glass, but a property of the set-up. The glass fails under compression when there is accidentally or incidentally some tension developed. The set-up never intends to develop such tensions, but it usually does for various reasons which are too technical for immediate discussion. If these tensions are bad enough, the glass breaks, whereupon the man making the test looks at the dial and records its reading as the compressive strength of the glass.

I have previously referred to the importance of mechanical strength in theory—the vision of recapturing the missing strength of glass. It ought not to be forgotten that even in its present lamentable state, the most valuable properties of glass are its mechanical properties. The most valuable pieces of glass in the world are the big telescope reflectors, the St. Gobain disk now at Mount Wilson, and Corning's 200-inch one at Mount Palomar. These are simply mechanical floors on which is buttered a thin reflecting film of silver or aluminum. The optical properties are of little interest, the mechanical properties all-important. Permanence of shape is the first requisite, great rigidity, and absence of plastic deformation.

In the case of commoner brands of glassware, strength is usually equally important, and as the subject is so abstruse, methods of testing are vitally important. We should like to know what we really determine by our existing tests. Manufacturers are usually trying, by testing, to insure that their product is as good as usual, *i.e.*, that their operations are proceeding normally.

It is held, legally, that tests are made to ensure that the product will be equal to any service it may be called upon to stand. This is going much further than the manufacturer wishes, for he does not know how roughly his ware is to be handled or how long it will be in use. A symposium, or series of symposia (for similar ones are to be held in England and Germany), to find out what we know at present about mechanical strength and methods of testing it, is a first step toward agreement on what tests to apply to a given class of ware and what we may reasonably feel that we know when the tests have been used.

BUTLER, PENNSYLVANIA

TESTS OF THE STRENGTH OF ELECTRIC-LAMP BULBS WITH SPECIAL REFERENCE TO THE TIME FACTOR*

By John M. McCormick

I. Introduction

One difficulty common to all tests of mechanical strength of glassware is the large variation of results obtained from apparently uniform samples, necessitating the testing of a large number of samples to strike an average. This factor assumes great importance in tests involving the time factor, especially for those tests in which the loading interval is long. (If we are to investigate the effect of sustained loads, we must use long periods of time in our tests since there is no way yet of estimating the long-time strength from results of tests of short duration.) A single figure or a single point on a curve, *e.g.*, the average strength after three hours for one specific group of samples, represents the result of three or four weeks of continuous testing. A complete investigation would require an almost unbelievable length of time. We are therefore obliged to report once more that the results obtained, though apparently sound, are not necessarily final.

The effect of sustained loading on glassware is, perhaps, of most direct interest to manufacturers of bottles. To make tests on bottles themselves involves difficulties due to their shape, which is complex at best. Bowes[1] has suggested that an attempt be made to determine the effect of sustained loading on simple-shaped objects. Glass laths and glass rods were suggested.

Glass laths, being cut from sheet or from plate, are subject to the variation in strength of the glass from which they are cut. Their cut edges introduce an element of uncertainty because of the possibility of local flaws caused by the cutting, and the determination of stress is complicated by the local disturbance caused by the knife edges used to apply the load. In all, they are not "simple objects" for test purposes. Preston has given a preliminary report of tests on laths.[2]

Glass rods, also, are not as simple objects for testing as they might seem, since it is difficult to apply the load without disturbing the stress distribution.

It seemed, therefore, that there might be merit in making tests on spherical glass shells for, if the shell be thin and the load be applied as internal hydrostatic pressure, the stresses in the glass should be relatively simple.

In the past the strength of electric-lamp bulbs has been a matter of considerable interest. Recently, Spencer[3] has suggested that information on prolonged tests of bulbs, or on tests of known duration, should be of value. Since electric-lamp bulbs approximate spherical shells, they seemed to offer both theoretical and commercial interest.

II. Experimental Set-Up

The primary objective in selecting samples for these tests was to obtain uniformity so that the results obtained might be comparable. Samples from the Corning "399" bulb machine were selected because the product of that type of machine might be expected to be fairly accurately spherical, fairly uniform in wall thickness, free from seams, free from metal chills, and, in fact mechanically ideal.

The two companies, "A," and "B," operating such machines kindly supplied several hundred bulbs each. The bulbs obtained from "B" are known as A21E1, and the shape and thickness of an individual specimen, as determined by the writer, is shown in Fig. 1. The composition as reported by the manufacturer of the bulbs is as follows:

"B" composition		"A" composition	
SiO_2	72.4%	SiO_2	71.4%
Al_2O_3	0.8	Na_2O	17.0
Fe_2O_3	0.4	Al_2O_3	1.3
CaO	5.3	CaO	5.4
MgO	3.7	MgO	4.0
Na_2O	17.4	K_2O	0.6

Since the bulbs were all made on the "399," presumably in normal operation, and the specimens in each lot taken from the same run under as nearly identical conditions as possible, it is probable that the individual specimens were more nearly alike than most industrial glassware.

The tests were made on a specially built testing machine which operated on the same principle as the precision-testing machine devised some time

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[1] U. E. Bowes, private communication.

[2] F. W. Preston, "The Time Factor in Testing Glassware," *Jour. Amer. Ceram. Soc.*, **18** [7] 222–23 (1935).

[3] C. D. Spencer, private communication.

ago.[4] The greatest difficulty was in effecting a good seal with the neck or base of the bulb. As manufactured, the base is irregular and has a sharp edge. It was possible to obtain a good seal, using the method in common use for bottles after grinding down the edge, but in bulbs broken using such a seal, the fracture almost always indicated trouble in the neck arising from the jaws which must be used to hold the bulb against the seal.

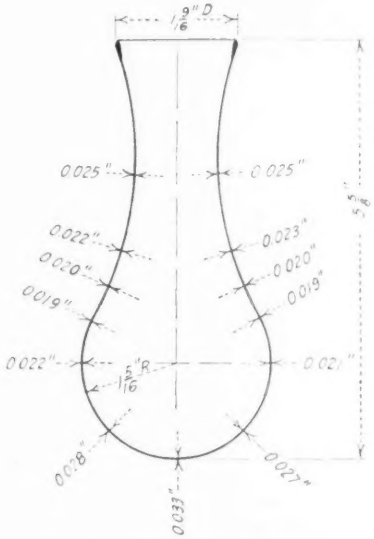

FIG. 1.—Cross-section of bulb.

Finally a special machine was made on which a thin-walled, soft-rubber sac, of approximately the size and shape of the inside of the bulb and permanently attached to the machine, acted as a container for the liquid (Fig. 2). With this device the water does not come in contact with the glass at all. The sac, being soft and thin and only slightly distended when in use, transmits virtually all the pressure to the glass. This arrangement has worked perfectly and, if a properly designed sac is used, replacements are few and easily made.

The load was applied in steps, the pressure being increased at definite intervals by equal increments of about ten pounds per square inch. Intervals of from five seconds to three hours were used.

III. Errors

The primary observations were those of pressure and of time. The machine used is so designed that the error in the observed pressure is negligible. The error in time is also negligible for all tests of more than about thirty seconds' duration. It is not negligible in the short tests because the increase in pressure can not be instantaneous, and a short time must elapse before the pressure attains its full value. The effect is that the time reported is probably slightly too long.

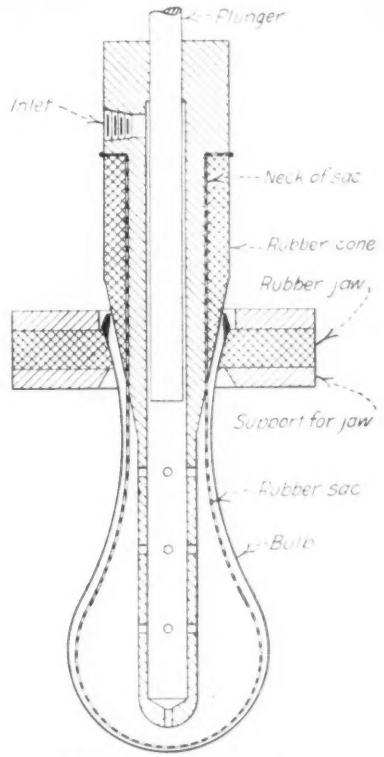

FIG. 2.—Detail of machine.

The tests reported as of five seconds' duration should perhaps be about three to four seconds.

The average deviation of individual values is low when compared with other tests of glassware. The probable error of the mean, as calculated from the deviation of individual values, is quite small, being of the order of 3% of the whole.

IV. Results

It was found that the specimens lacked that uniformity which was sought; that almost all were slightly out of round, some considerably so; and that the thickness was by no means uniform around the periphery. The very conditions which were thought to simplify the investigation complicated it, for it seems that the minor variations in shape and structure play an important part in determining the stresses which result in failure.

[4] F. W. Preston, "Pressure-Testing Machines," *Glass Ind.*, **15** [10] 252 (1934); *Ceram. Abs.*, **14** [2] 45 (1935).

NOTE: A few measurements were made of the deformation which takes place during the test. As pressure is applied, the shape usually tends to become less elliptical (in one instance the opposite behavior was observed). This change of shape must cause stresses from a bending action. The calculated value of the stress introduced in this manner, assuming the bulb to be initially 0.010 inch out of round (not an unusual amount), is of the order of 1000 pounds per square inch. The calculated value of simple tensile stress resulting from a pressure of 100 pounds per square inch is of the order of 4000 pounds per square inch.

A tabulation of the results obtained is given in Table I.

TABLE I

SUMMARY OF RESULTS

Duration of test	No. broken	Average breaking load (lb/sq. in. pressure)	Probable error of Mean* (lb/sq. in. pressure)	Probable error of Individual values† (lb/sq. in. pressure)
		"B" Clear		
5 sec.	20	107	3.7	16.7
1 min.	20	89	3.5	15.9
15 min.	21	76	2.4	11.1
3 hr.	12	74	3.2	10.0
		"B" Frosted		
5 sec.	20	116	2.2	9.7
1 min.	20	97	2.5	11.3
15 min.	15	85	2.6	10.3
3 hr.	10	81	2.3	11.0
		"A" Frosted		
5 sec.	7	124	3.0	8.0
10 sec.	6	103	1.5	3.0
1 min.	10	80	2.7	8.5
5 min.	10	81	3.7	11.5
30 min.	11	78	3.8	12.4
3 hr.	5	75	3.9	8.8

* From the equation, $r_0 = 0.6745\sqrt{\frac{\Sigma v^2}{n(n-1)}}$.

† From the equation, $r_s = 0.6745\sqrt{\frac{\Sigma v^2}{n-1}}$.

Where v = variation of individual values from arithmetical mean.

A comparison of the strengths at different loading intervals is given by the curves of Figs. 3 and 4.

In all cases a definite decline in strength as the interval is increased is apparent. The rate of decline here is much less than that observed for laths and is comparable with that found for bottles.[2]

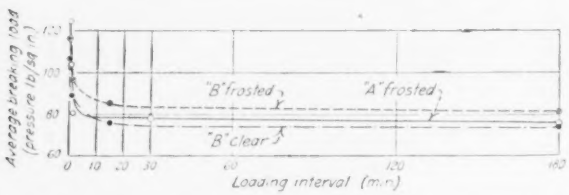

FIG. 3.—Effect of duration of loading on strength of electric-lamp bulbs.

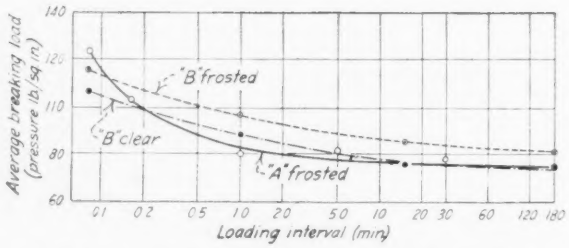

FIG. 4.—Effect of duration of loading on strength of electric lamp bulbs.

There is a decrease in the rate of decline of strength for the longer periods, the strength appearing to approach a definite minimum value. In other words, it appears that there is a moderate stress which the glass will endure forever. This is in accord with the views of Littleton and others, but is contrary to the tentative view expressed by Preston earlier.[2]

There appears to be a marked difference in the rate of decrease of strength of the bulbs from "B" and those from "A," the latter bulbs having a higher initial strength but falling off more rapidly, so that at a moderate time, *e.g.*, one minute, the strength is less than that of the "B" bulbs. On a long-time test the strengths are about the same. It is possible that this difference is caused by differences in composition, or it may be a matter of annealing. In the polariscope, the "A" bulbs show slightly more disannealing.

It also appears that the commercially frosted bulbs are superior in strength to the clear ones. (Tests were also made on clear "A" bulbs, but the results showed such discrepancies as to lead to the conclusion that the samples tested were not strictly comparable.) The superiority of the frosted bulbs persisted for all durations of test.

(1) Comments

No simple law has been found to connect strength with duration of test. Grenet's results[5] in cross-bending tests plot to a straight line if the average breaking stress is plotted against the logarithm of the duration of test. Our tests on bottles[2] also plot to a straight line in most instances. Our results, however, for laths and these for bulbs show definite positive curvature

[5] Grenet, *Bull. soc. encour. ind. nat.* [Ser. 5], **4,** 838 (1899); partial English version, *Glass Ind.*, **15** [11] 277–80 (1934); *Jour. Amer. Ceram. Soc.*, **18** [7] 221 (1935).

when plotted in that manner. There is little theoretical ground for expecting such a law to hold. If the relation is to be a logarithmic (exponential) function, it would seem more logical for it to be one in which the straight line comes from plotting the logarithm of stress against the duration of test. The shape of the curve is more nearly that of a translated rectangular hyperbola, approaching asymptotically the axes, time equals zero ($t = 0$), and the finite minimum stress value ($f = f_{t \to \infty}$), which was mentioned.

V. Location and Nature of the Fracture

The most common failure shows a small area (presumably the point of origin of the fracture) about $^1/_8$ to $^1/_4$ inch long, in a plane containing the axis of the bulb, and located, not in the spherical portion, but in the portion which joins it to the more or less cylindrical neck. From this point cracks branch out, including an angle of about 90 degrees. It is usual for fans of cracks to spread both into the neck and into the spherical portion; however, when the origin is well up on the neck, it is not uncommon for the fan into the neck to be missing, a single crack then running through its entire length.

The degree of subdivision of the fan of cracks is, in general, greater the higher the pressure at which rupture occurs. Splinters were measured which were as small as a two-degree segment of the spherical surface. The angle at which a new crack branches away from its parent is, however, rarely less than 15 degrees.

VI. Conclusions

As has been explained, these results are not to be regarded as complete. Sweeping generalizations based on such limited data must be avoided.

It appears to be established that if a piece of ware will stand up under a certain load for a few hours, it will endure nearly as great a load for weeks, or possibly forever. In practice, it would be impossible to test all ware for hours. In that case the duration of the test that *is* made must be known with precision, and allowance must be made for the known fact that the ware will not stand indefinitely a stress as high as the experimental value obtained in short tests.

Butler, Pennsylvania

MODULUS OF RUPTURE AND THERMAL-SHOCK RESISTANCE AT ELEVATED TEMPERATURES*

By J. S. Gregorius

I. Modulus of Rupture

The modulus of rupture of flat strips was observed at room temperature, 200°F, and at intervals of 100°F up to and including 1000°F.

The apparatus used was a breaking machine of a cantilever type. The specimen support was a cast-iron beam on the top face of which were mounted two $^1/_4$-inch round steel rods on 8-inch centers. The force application was accomplished by a cantilever beam, the fulcrum of which was located external to the heating furnace and at such a position that the ratio of power arm to weight arm was 2 : 1. The force was applied by falling "shot" so controlled that the flow of shot was arrested instantaneously with rupture. The furnace employed was of the electrical-resistance type.[1] The strips of glass used were annealed so as to possess a residual stress equivalent to 20 to 30 mμ birefringence per inch of glass path.

The modulus of rupture was observed on five specimens at each interval of temperature. The average of such observations was recorded and, by using the room temperature modulus as a base of 100, the relative strength values at various temperatures were expressed.

Glasses of two types, to be designated as glass No. 1 and glass No. 2, were investigated. Their analyses follow.

	Glass No. 1	Glass No. 2
SiO_2	72.31	71.54
Na_2O	12.90	13.50
CaO	10.60	12.85
MgO	2.73	0.16
Na_2SO_4	0.74	.99
NaCl	.08	.14
R_2O_3	.64	.82

The rupturing modulus and strength values of the two glasses follow.

* Received December 31, 1935.

[1] Manufactured and sold by the Hoskins Mfg. Co.

GLASS NO. 1

(Specimen $1^1/_2$ by 10 by 0.10 inch)

Temp. (°F)	Modulus of rupture (lb./sq. in.)	Strength value
80	10,666	100
200	11,042	103
300	10,950	103
400	9,594	90
500	9,784	92
600	8,490	80
700	12,904	121
800	13,000	122
900	14,781	138
1000*	14,100	132

* Specimens deformed under load.

GLASS NO. 2

(Specimens $1^1/_2$ by 10 by 0.125 inch)

80†	9458	100
600	7560	80
700	7014	74
800	7260	77
900	8354	88

† The interval from 80 to 600°F was omitted due to the limited number of specimens.

The annealing range of glass No. 2 was 25 to 35°F higher than that of No. 1.

The conclusions permissible from these observations are as follows: (1) the modulus of rupture decreases with rise of temperature; (2) the modulus of rupture decreases with rise of temperature until such temperature is reached where modulus appears to increase. It is quite probable that this phenomenon is associated with flowage and that the modulus would continue to decrease if the load could be applied in zero time; (3) the apparent minimum moduli of glasses No. 1 and No. 2 were at the approximate temperature of 600°F and 700°F, respectively.

II. Thermal-Shock Resistance

For the thermal-shock test, specimens 2 by 2 by 0.288 inch were ground on the edges, slightly beveled, and then annealed so that the residual stress was 20 to 30 mμ birefringence per inch of glass path. In producing the thermal shock, the specimen was placed in a wire basket attached to a wire handle of suitable stiffness and, in the high temperature observations, heated in an electric furnace to a prechosen temperature. Upon attaining practical equilibrium of temperature, the specimen was quickly removed from the furnace and plunged into a cooling bath maintained at a prechosen temperature. The cooling-bath temperature was kept constant and the furnace temperature was increased in increments of 5°F until rupturing occurred. If the same differential caused rupturing of a second specimen, the value was accepted as indicating the thermal endurance at that bath temperature.

The most acceptable conception in visualizing the mechanics of breakage resulting from a thermal shock is as follows: The chill or thermal drop required to rupture a glass specimen is an expression indicating the resistance to thermal shock of the specimen at the temperature of the chilling medium. Conceive a plate of annealed glass, such as the specimens were, at a uniform temperature. Because it was previously annealed, the specimen in its heated condition is free of stress. Upon plunging it in a cooling medium, this freedom of stress is replaced by a development of stress which arises from the effort of the shell to contract upon chilling. This action throws the shell into tension and the core into compression. Glass being predominately stronger in compression than in tension, the failure of the specimen occurs in tension and the shell ruptures. Hence, it is clear that when rupturing occurs in the chilled shell the thermal drop necessary to cause rupture is an expression involving the tensile strength, coefficients of expansion and elasticity, and diffusivity of the glass at the temperature of the chilling medium.

Winkelmann and Schott give the following formula for the coefficient of thermal endurance:

$$K = \frac{\text{tensile strength}}{\text{coeff. of expan.} \times \text{elas.}} \cdot \sqrt{\frac{\text{thermal conductivity}}{\text{specific heat} \times \text{density}}}$$

Where K = thermal endurance.

The term, $\sqrt{\frac{\text{thermal conductivity}}{\text{specific heat} \times \text{density}}}$, is the square root of diffusivity.

The diffusivities of the several materials used in these observations follow.

Paraffin	0.00098
Water	.0014
Glass	.0057
70% Sn 30% Pb	0.356

III. Limitations of Water as a Chilling Medium

It was thought that if a specimen were heated to a temperature above the boiling point of the liquid used as the chilling medium, the heat of vaporization would absorb heat from the specimen with a corresponding decrease in apparent resistance to thermal shock. The comparison of temperature-drop tolerance in specimens chilled from 200°F and 300°F in water confirms this interpretation.

Glass temp. (°F)	Temp. of water bath (°F)	Temp. difference to cause rupture (°F)
300	195	105
200	50	150

Other factors playing important rôles are the wetting ability and the convection movements of the chilling medium. Water probably possesses these two properties in an admirable degree, but the heat of vaporization precludes its use when the thermal shock at elevated temperatures is investigated. For this reason paraffin and a molten alloy of tin and lead (70% Sn, 30% Pb, melting point 365°F) were employed.

In this investigation, to obtain thermal-shock values below a quenching temperature of 400°F, paraffin was used as the quenching medium. The range of the two quenching mediums overlapped; hence, it was considered permissible to extrapolate the values of the tin-lead group to 200°F by the relation of the overlapping values. These observations follow.

GLASS NO. 1*

Glass temp. (°F)	Temp. of chilling batch (°F)	Rupturing differential (°F)
1215	1000	No rupture
1200	900	" "
905	800	105
630	500	130

* A limited number of specimens prevented investigation below 500°F.

GLASS NO. 2

Glass temp. (°F)	Temp. of chilling bath (°F)	Rupturing differential (°F)	Thermal resistance (using value at 200° chilling bath as 100)
1215	1000	No rupture	
1010	900	110	55
910	800	110	55
820	700	120	59
745	600	145	72
665	500	165	82
575	400	175	87
487†	300	187	93
402†	200	202	100

† Extrapolated values based on paraffin.

IV. Conclusions

(1) The resistance to thermal shock decreases with increase of specimen temperature until the lower limits of the annealing range is reached. When the temperature of the chilling medium is in this range, the resistance to thermal shock apparently rises toward infinity. The annealing range of glass No. 1 is lower than that of glass No. 2. In the case of glass No. 1, this zone was reached at 900°F. In the case of glass No. 2, this zone was not reached until 1000°F was attained. The temperature steps are much too rough for a precise determination of the zone mentioned.

(2) Glass ruptures upon chilling when the chilling stress exceeds the thermal resistance of the glass. From the conception of the mechanics involved, the tensile strength of the glass is probably the most influential factor with coefficient of expansion next in influencing resistance to thermal shock.

(3) Glass, in chilling, always ruptures in the outer layers of the specimens.

The following studies are suggested for further investigation:

(1) Locating with more precision the temperature of chilling medium where the thermal resistance appears to rise to infinity.

(2) Determination of the modulus of rupture and thermal-shock resistance at sub-room temperatures.

(3) Development of a method of determining tensile strength in which uncontrollable variables are at a minimum.

RESEARCH LABORATORIES
PITTSBURGH PLATE GLASS COMPANY
CREIGHTON, PENNSYLVANIA

EFFECT OF THE RATE OF LOADING ON THE BREAKING STRENGTH OF GLASS*

By L. V. Black

I. Introduction

It has been known for some time that no definite, concrete figure can be given for the breaking strength of glass. This property is affected by many variables which ordinarily are not considered in measuring the strength of other materials such as steel and concrete. Among these are (1) the condition of the surface, such as scratches, poor finish, stain, etc., (2) unknown physical characteristics of the glass itself which cause a wide variation of the breaking strength of individual samples cut from the same plate, and (3) the rate at which the load is applied to the glass.

The effect of the rate of loading is the subject of the following study.

II. Test Specimens

Eighty samples of plate glass, 2 in. by 10 in. and approximately $^{7}/_{64}$ in. thick, were used.[1] These samples were cut from a single plate that was cast July 2, 1935. All samples were carefully examined and found to be of excellent quality and free from any surface defects. Each specimen was measured carefully to 0.001 in. in thickness and 0.01 in. in width. Ten samples were used for each test and the average modulus of rupture value of the lot was taken to minimize the effect of the second variable mentioned.

III. Method of Test

The glass was broken by supporting on two parallel $^{3}/_{8}$-in. diameter cold-rolled steel rods exactly 8 inches apart. A third steel rod, attached to a lever, pressed on the opposite side of the glass parallel to and exactly midway between the supports. The force was applied to the lever by means of water running into a pail, through a valve, and from a constant level source. The stream of water was directed against the side of the pail so that its force was not transmitted to the glass. The rate of flow of the water was carefully adjusted before each test and the valve was left set in that position for the duration of that test. A second quick-acting valve in the line turned the water supply on and off.

After each specimen was broken, the water in the pail was carefully weighed. The time the water was flowing was also measured with a stopwatch for each specimen, and this time was checked against the desired rate of flow of the water. The modulus of rupture of each sample was calculated from the formula,

$$M = \frac{3PL}{2BD_2}.$$

The rate of loading for each succeeding test was increased by a factor of three and varied from a minimum of 35 pounds in 2430 seconds to a maximum of 35 pounds in ten seconds.

Table I shows the results.

TABLE I

Test No.	Rate of loading 35 lb. (sec.)	Thickness (in.)	Time (sec.)	Pounds	Modulus of rupture (lb./in.²)
		Minimum			
1	10	0.117	5.2	19	8360
2	30	.117	13.9	16.25	7160
3	90	.117	38.2	14.9	6570
4	270	.117	90.0	11.9	5250
5	810	.120	348.0	14.6	6140
6	2430	.118	780.0	11	4750
		Average			
1	10	0.117	7.0	24.3	10765
2	30	.115	17.7	20.6	9042
3	90	.117	45.0	17.5	7701
4	270	.117	120.0	15.9	7044
5	810	.117	360.0	15.6	6913
6	2430	.114	960.0	14.0	6494
		Maximum			
1	10	0.115	10.2	35.5	16100
2	30	.116	25.9	30.25	13600
3	90	.117	49.9	19.4	8550
4	270	.125	180.0	23.0	8900
5	810	.113	406.0	17.5	8330
6	2430	.115	1260.0	18.0	8250

The remaining two sets of 10 samples each were placed on supports 8 inches apart and a load of 7 pounds suspended from the center of each specimen of the first set and 10 pounds suspended from each specimen of the second set. The 10-pound load was less than the breaking load of any of the samples of the above tests and was approximately one-half the average breaking load of the 30-second test. These tests were left for 20 days and checked at least every 24 hours for the number of samples broken.

* Received January 27, 1935.

[1] From the Creighton plant of the Pittsburgh Plate Glass Co.

IV. Results of Tests

In the 10-pound test, one sample broke at the end of one hour, a second broke in $1^1/_2$ hours, 4 were broken at the end of 4 hours, 2 at the end of 17 hours, and 1 at the end of 40 hours. The tenth sample of this test was not broken at the end of 20 days and, when broken at the end of that time by loading with 35 pounds in 30 seconds, a modulus of rupture of 9050 pounds per square inch was observed. In the case of the ten samples loaded with 7 pounds, one broke in seven days and the others were not broken in 20 days. Their average modulus of rupture when they broke at the end of that time by loading with 35 pounds in 30 seconds was 8244 pounds per square inch.

None of the unbroken samples in these tests had taken a permanent set.

Sustained Loading Tests

10-lb. load ($^1/_2$ av. breaking load when applied at rate of 35 lb. in 30 sec.)

1 broke in 1 hr.
1 " " $1^1/_2$ hr.
4 " " 4 hr.
2 " " 17 "
1 " " 40 "
1 not broken in 20 days
Modulus of rupture of unbroken sample 9050

7-lb. load

1 broke in 7 days
9 not broken in 20 days

Modulus of rupture of unbroken samples

Minimum 6650 lb./in.^{2} Average 8244 lb./in.^{2}
Maximum 12,910 lb./in.^{2}

V. Conclusions

(1) Because of the wide variations of the above values it seems highly desirable that authorities interested should formulate specifications of standard rates of loading for measuring the strength of glass. If the span and width of the test samples were standard, the rate of loading should probably vary as the square of the thickness of the glass, so that the time of rupture would take place for all thicknesses in approximately the same time.

(2) The modulus of rupture of ordinary glass varies from a maximum of about 16,000 pounds per square inch when the load is applied in a short period of time to a minimum of about 3000 pounds per square inch when the load is sustained for a long period of time. Other tests have shown that glass whose surface is scratched, sandblasted, or stained may have a modulus of rupture lower than this minimum value. It is recommended, therefore, that in calculating the strength of glass a low modulus of rupture value be used and, in addition, a large factor of safety be allowed.

(3) Glass that has been loaded for a long period of time is immediately restored to very nearly its original strength as soon as the load has been removed.

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ACTIVITIES OF THE SOCIETY

ENAMEL DIVISION REPORT OF COMMITTEE ON STANDARDIZATION OF TESTS*

(A) DEVELOPMENTS DURING 1935 AFFECTING STANDARDIZED TESTING IN THE ENAMEL INDUSTRY

By D. G. Bennett

Abstract

Wider uses of and refinements in porcelain enamel bring up new testing angles. Precision instruments, often developed for use in other fields, are finding their way with but slight modification into the enamel industry. The application of modern test methods to enamel troubles hitherto unsolved is frequently indicated.

I. Introduction

The Committee on Standardization of Tests, which is a standing committee of the Enamel Division, should be a repository of information on tests that are, or may be made, available. Another service that might be rendered is collecting and presenting evidence of the need for tests.

In the pursuit of these objectives a survey of the material published in 1935 and the early part of 1936 has been made. At first thought, the section of time investigated might seem "too thin" to be significant, but experience is cumulative and so it is with tests. As it was, only a portion of the available literature could be investigated owing to its extent and to the limited time available.

II. Enameling Iron

Aydelott and Pfeiffer[1] sag-tested 9-inch strips of iron spanned between supports and heated for 10 minutes at 1600°F. Iron suppliers studied this test and produced an iron that sagged a few tenths of an inch as opposed to the former sag of several inches.

A test of this kind should be important to all enamel shops. With various enameling irons rated on their ability to resist warping, the enameler should be in a position to specify performance that might not be otherwise offered.

Rosenberg[2] suggests that copperheading may be due to excessive oxidation of the steel and that studies of the vast amount of data on composition of iron *versus* its rusting should aid in solving the copperheading problem.

Any test derived from the above considerations, by means of which the performance of the steel could be predicted, should be valuable.

III. Screen Fineness Tests

The residue on 200-mesh, fineness test has not been found to be altogether satisfactory in the ordinary two cover-coat enameling process. Pfeiffer and Aydelott[1] use an old screen for the first wash to save the standard screen somewhat from too frequent plugging. Beasley,[3] in stressing fineness control, notes that screen tests are not accurate owing to the presence of foreign material in the meshes. Spencer-Strong[4] attaches great importance to screen tests but notes that the screens fail frequently and he points out the needless expense of additional grinding that may be wrongly indicated.

In one cover-coat work, Bryant[5] advocates fine grinding to promote opacity. Matthes[6] uses almost double-milling time for one-coat enamels. Holscher[7] says that fine-milled slips show 12.0 to 0.2% on 325-mesh. Thus one cover-coat work tends to put the screen test to a greater strain.

Suggestions for other methods come from Fabianic,[8] who discusses screening, water and air elutriation, and microscopic count. Schwartzwalder and Herold[9] describe the Wagner turbidimeter which consists of a source of light of constant intensity which passes through a liquid

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, April 1, 1936 (Enamel Division). Received April 3, 1936.

[1] E. C. Aydelott and W. H. Pfeiffer, "Enamel Shop Control," *Better Enameling*, **6** [3] 12–17 (1935); *Ceram. Abs.*, **14** [6] 133 (1935).

[2] J. E. Rosenberg, "Relationship between Copperheading and Fishscaling," *Ceram. Ind.*, **25** [4] 206–208, 228 (1935); *Ceram. Abs.*, **15** [1] 11 (1936).

[3] H. C. Beasley, "Temperature and Fineness Control of Ground Coats for Sheet Steel," Abs. in *Ceram. Age*, **25** [3] 97 (1935).

[4] G. H. Spencer-Strong, "The Importance of Screen Care in Enamel Fineness Control," *Amer. Enameler*, **8** [8] 3–4, 12 (1935); *Ceram. Abs.*, **15** [5] 145 (1936).

[5] G. L. Bryant, "Single Cover-Coat Demands Changes and Control in Enameling Processes," *Ceram. Ind.*, **24** [6] 354 (1935); *Ceram. Abs.*, **14** [8] 183 (1935).

[6] A. L. Matthes, "Factors in One Cover-Coat Enamel," *Ceram. Ind.*, **24** [5] 276 (1935); *Ceram. Abs.*, **14** [7] 157 (1935).

[7] F. R. Porter and H. H. Holscher, "Use of Finely Milled Enamel Slips," *Jour. Amer. Ceram. Soc.*, **18** [2] 39–42 (1935).

[8] W. L. Fabianic, "Microscopic Control of Particle Size in Refractory Manufacture," *ibid.*, **18** [1] 23–25 (1935).

[9] K. Schwartzwalder and P. G. Herold, "The Effect of the Solid-Liquid Ratio on Grinding a Ceramic Nonplastic," *ibid.*, **18** [11] 350–52 (1935).

suspension of nonplastic material to a photoelectric cell where the current generated is measured by a microammeter.

IV. Thickness Tests

The use of one cover-coat enamels has accentuated the problem of weight, or thickness control, while it is present as usual in other types of enameling.

Matthes,[6] who stresses close control of spray weight, states it will vary from 20 to 30% if not watched. Porter and Bryant[10] found that variations of a few grams per square foot in coat weight would cause color-matching difficulties. Cooke[11] has used routine weighing before and after enameling. Aydelott and Pfeiffer[1] use color matching tests to detect overweight enamel so that it can be withdrawn from further processing.

Holscher[12] suggests that off-color enamel is not always due to extra thickness and that the electric thickness gage can be used advantageously to check thickness either in the dry or fired conditions and on flat or beaded surfaces. A description of the electric thickness gage[13] presents it favorably as a precision instrument of practical utility.

V. Furnace Conditions

Information on furnace-heat distribution is desirable but not always available. From it, the best ware arrangement and chain speed (in continuous furnaces) can be determined. It can be made the basis for proper burner arrangement or adjusted heat input. It has been found that in some cases a reduction in ware preheat time has resulted in relief from copperheading.

Aydelott and Pfeiffer[1] have used "sag strips," sending them concurrently through a continuous furnace, at the top and bottom of a firing tool and then, if necessary, adjusting the heat so that subsequent strips sag equally.

Irwin [14] checked furnace firing conditions by sending 100 feet of thermocouple around with the ware. By this means, position-temperature curves for both furnace and ware were obtained. By a modification of this method, box-type furnaces can be investigated for hot and cold spots.

The importance of investigating furnace atmospheres must be recognized. Canfield,[15] in discussing copperheads, says that few data have been obtained on the composition of gases evolved from the enamel which might accumulate in the furnace and influence oxidation. Correlated with this, in an article from another source,[16] the build-up of objectionable gases in electric furnaces is recognized, as are also those resulting from combustion in fuel-fired furnaces. Generous venting is suggested in lieu of adequate tests.

On the other hand, the American Gas Association[17] determines CO in the products of combustion according to a method developed by the Bureau of Standards, whereby CO is oxidized by iodine pentoxide at a temperature of about 300°F.

Ebright, McIntyre, and Irwin[18] have described a method for identifying and measuring the gases present in a furnace by means of phosphorous pentoxide, ascarite, and $CaCl_2$ in conjunction with the regular Orsat apparatus. The advantages to be gained by use of this method seem to be definite, for by its use individual furnaces were found to be "temperamental" in that each had its definite conditions under which best results were secured.

VI. Copperheading and Reboiling

These defects are considered under one heading because data on certain phenomena of viscosity, flow, and surface tension probably apply to both.

Canfield,[15] in discussing copperheading recommends greater solvent capacity for iron oxide and lower flow temperatures as desirable enamel properties. He shows a curve of softening point plotted against Fe_2O_3 content for an enamel. It is possible that from the curves of a series of enamels plotted on this basis, a relationship could be worked out that would serve to evaluate the copperheading resistance of a ground coat. It is also possible that the dip and subsequent rise in softening points would be reflected in the reboiling tendencies of the enamels.

Barrett and Taylor[19] have presented methods for evaluating the flow characteristics of glasses. It seems that the ability to heal over a blister is involved here. Parmelee[20] took surface-tension measurements by the "maximum-bubble-pressure" method. Undoubtedly the effect of surface tension merits careful consideration. The Bureau of Standards[21] is determining the viscosity of enamels at firing temperatures. Ground coats are found to be truly viscous. Cover coats are not.

Rosenberg[2] suggests that a study of the data on iron composition *versus* its rusting should help solve the copperheading problem.

VII. Adherence

In considering tests for adherence, some speculation as to what causes adherence can scarcely be avoided.

Kinzie and Miller[22] have reported a method for testing

[10] F. R. Porter and G. L. Bryant, "One Cover-Coat Enamel Finishes," *Bull. Amer. Ceram. Soc.*, **14** [11] 367–69 (1935).

[11] R. D. Cooke, "Laboratory Control in Dry-Process Enameling," *ibid.*, **14** [11] 373–74 (1935).

[12] H. H Holscher, "Use of the Thickness Gage in Porcelain Enameling," *Better Enameling*, **6** [10] 16–17, 30 (1935); *Ceram. Abs.*, **15** [2] 57 (1936).

[13] News Item, "Electric Gage for Enamel Thickness," *Enamelist*, **13** [2] 12 (1935).

[14] J. T. Irwin, "Checking Furnace Firing Conditions," *Enamelist*, **12** [4] 18–19, 46 (1935); *Ceram. Abs.*, **14** [4] 87 (1935).

[15] J. J. Canfield, " 'Copperheads' or Iron-Oxide Defects in Porcelain Enamel," *Better Enameling*, **6** [6] 19–20, 25 (1935); *Ceram. Abs.*, **14** [8] 182 (1935).

[16] Editorial, "Furnace Atmosphere," *Better Enameling*, **6** [9] 13–14 (1935); *Ceram. Abs.*, **15** [2] 56 (1936).

[17] H. E. Martin, "Big Laboratory Does Marvels in Gas Industry," *Enamelist*, **12** [10] 12–13, 53, 59–60 (1935).

[18] H. E. Ebright, G. H. McIntyre, and J. T. Irwin, "A Study of Furnace Atmospheres and Temperature Gradients and Their Effect on Porcelain Enameling," *Jour. Amer. Ceram. Soc.*, **18** [10] 297–302 (1935).

[19] E. P. Barrett and J. A. Taylor, "A New Method for Studying Flow Characteristics of Glasses and Slags at Elevated Temperatures," *ibid.*, **19** [2] 39–44 (1936).

[20] News Item, "Insulation of Furnaces and Use of Cullet Discussed at Illinois Glass Conference," *Ceramic Ind.*, **25** [1] 36, 44 (1935).

[21] News Item, "Consistency of Enamels at Firing Temperature," *ibid.*, **25** [6] 346 (1935).

[22] C. J. Kinzie and J. B. Miller, "A Method for Testing Adherence of Ground Coats to Metal," *Bull. Amer. Ceram. Soc.*, **14** [11] 371–73 (1935).

the adherence of ground coats to metal. The apparatus is essentially an Arbor press equipped to press a steel ball into an enameled sheet a definite distance.

Clark,[23] investigating with X-rays, says that evidences of a skin of glass in which a truly crystalline condition is approached have been obtained frequently in his laboratory. "Evidently at an interface between molten glass and a mold or core surface there is a favorable condition for more perfect molecular arrangement. . . ." Work such as this, when tied in with a consideration of crystal forms, atomic radii, and interatomic forces of the substances contained in a ground-coat glass and in the iron in contact with it, furnishes material for some interesting fundamental theorizing.

Barrett and Taylor[19] have developed a technique for the determination of the temperature at which the solid-liquid interfacial tension becomes low enough to permit wetting of a solid by a glass or slag. Measurements of the changing contact angle between solid and fusing glass billet are made as the temperature rises.

VIII. Chipping

The phenomenon of enamel chipping may be considered, in any case, as a function either of the enamel *per se* or the manner in which it is used. An effective approach to relief from chipping must consider both.

Kinzie and Commons[24] correlate enamel expansion curves with chipping tendencies. Their method may constitute test procedure if properly verified as to results.

Holscher[25] shows that losses by chipping in parts with enamel above 0.021 inch in thickness are six times those with enamel below this thickness. He advocates[12] the use of the G. E. thickness gage as a means of control.

Holscher[26] has also found that on ware with a radius of curvature of less than $^9/_{64}$ inch chipping is acute. His results suggest that standard test specimens with a critical radius of curvature might well be used to evalute the relative chipping tendencies of any series of enamels.

IX. Acid Resistance

It has been noted [27] that in recent years the problem of acid resistance has become less pressing. Advancing technique has undoubtedly made possible more resistant enamels with less sacrifice of working properties. Nevertheless, the problem of acid-resistant enamels is one frequently referred to the Standardization of Tests Committee during the past two years.

Probably because of several outbreaks of food poisoning in recent years, current English articles have paid particular attention to acid resistance. It is suggested that specifications for resistance be determined within the industry.

Donovan[28] states that in several brands of New Zealand enamelware, dangerous amounts of Sb were dissolved from the enamel by acid foods. Burns,[29] who considers that Sb_2O_3 and Sb_2O_5 are soluble in citric acid and that Sb_2O_4 is not, cites tests and advocates the total prohibition of Sb in enamelware. McLachlan and Matthews[30] described an outbreak of Sb poisoning in England from lemonade in enameled vessels. This article seems to be based almost wholly on the findings in an English bulletin[31] which describes the outbreaks, gives tests, and suggests that the question of Sb in hollow ware be disposed of in one of several ways. This bulletin considers pentavalent antimony as being the insoluble form. Coste and Garratt[32] give tests for cooking vessels for use in public institutions under the London City Council. In this case boron and fluorine are also considered as being toxic. King[33] has shown that there may be a correlation between the electrodialysis results and corrosion resistance of a glass. Turner[34] advocates tests on glass grains rather than glass surfaces for corrosion resistance.

An interesting period to the above summary is put by Stuckert,[35] who says that enamel linings highly resistant to acids have been completely successful only with cast iron and that sheet-iron linings are only relatively resistant. There may be some difference of opinion as to the location of the two types of enamel within the limits suggested by Dr. Stuckert.

X. Abrasion

The highest possible resistance to abrasion will always be sought for enamel surfaces. Horak and Sharp[36] approach the problem in a fundamental way, holding that in general

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[23] G. L. Clark, "X-Ray Is Answering the Question 'What is Glass'," *Ceram. Ind.*, **24** [1] 34–38 (1935); *Ceram. Abs.*, **14** [3] 68 (1935).

[24] C. J. Kinzie and C. H. Commons, Jr., "A Discussion Relating to Thermal Expansion Methods from Theoretical and Practical Standpoints," *Jour. Amer. Ceram. Soc.*, **18** [10] 306–308 (1935).

[25] H. H. Holscher, "Relation between Chipping and Thickness of Porcelain Enamel Coatings," *Ceram. Ind.*, **24** [6] 348–49 (1935); *Ceram. Abs.*, **14** [8] 183 (1935).

[26] H. H. Holscher, "Minimum Radius of Curvature for Enameled Parts," *Bull. Amer. Ceram. Soc.*, **14** [11] 369–71 (1935).

[27] E. P. Poste, "What 1934 Has Contributed to the Vitreous Enamel Industry," *Ceram. Ind.*, **24** [4] 230–34, 242–44 (1935); *Ceram. Abs.*, **14** [6] 134 (1935); [7] 157 (1935).

[28] W. Donovan, "Antimony in Enamelware," *Analyst*, **60** [707] 103 (1935); *Ceram. Abs.*, **14** [7] 157 (1935).

[29] R. H. Burns, "Antimony Compounds Extracted from Enamelware by Citric-Acid Solutions," *Analyst*, **60** [709] 220–22 (1935); *Ceram. Abs.*, **14** [9] 210 (1935).

[30] T. McLachlan and D. M. Matthews, "Poisonous Metals in Foodstuffs," *Food Manufacture*, **10** [9] 325–27 (1935); *Ceram. Abs.*, **15** [2] 55 (1936).

[31] G. W. Monier-Williams, "Antimony in Enameled Hollow Ware," *English Ministry of Health Bull.*, No. 73 (1934); *Ceram. Abs.*, **14** [1] 3 (1935); [2] 32 (1935).

[32] J. H. Coste and D. C. Garratt, "Acid-Resistance Specification for Enameled Hollow Ware," *Analyst*, **60** [709] 215–19 (1935); *Ceram. Abs.*, **14** [9] 210 (1935).

[33] R. M. King, "Mechanics of Enamel Suspension: II, Electrodialysis of Some Enamels and Glasses," *Jour. Amer. Ceram. Soc.*, **18** [8] 230–33 (1935).

[34] W. E. S. Turner, "The Chemical Durability of Glass," *Bull. Amer. Ceram. Soc.*, **14** [5] 165–69 (1935).

[35] L. Stuckert, "Acid-Resisting Enamels," *Chem. Markets*, **33** [3] 238–39 (1933); date incorrectly given as 1935 in *Ceram. Abs.*, **14** [11] 269–70 (1935).

Since this review was written, a check-up shows that Dr. Stuckert's article was published in 1933 and not in 1935 as shown in the *Ceram. Abs.* reference. The paragraph above was allowed to stand, however, as a mile-post along the highway of progress.

[36] W. Horak and D. E. Sharp, "Note on Influence of Zirconia on Elasticity of Some Soda-Lime Glasses," *Jour. Amer. Ceram. Soc.*, **18** [9] 282–84 (1935).

any lowering of the modulus of elasticity will result in a tougher glass that is less likely to be marred or scratched by rough handling.

Spencer-Strong[37] has presented a sand-abrasion machine in which sand passing through a funnel is caught by a fan and thrown against the enamel plate. The machine is said to be adjustable over a wide range from a mild abrasive to a destructive test. The same principle is employed in the wheelabrator-sandblasting machine.

In another type of test,[20] a diamond point is pulled over the glass surface under controlled conditions. This test was found to be selective enough to differentiate between changes in glass finishing and certain changes in composition.

XI. Enamel Strength

Mechanical strength in enamel is an important property, and it has been studied during the year. Corning Glass Works[38] finds differences, due to composition, in mechanical strength of as much as 1 to 2 between the strongest and weakest glasses. In their special low-expansion (Pyrex-brand) field a range of 20% is found. Horak and Sharp[36] determined various moduli of enamel glasses by load and flexure methods. Gregorius[39] noted that a fiber of glass has more tensile strength than a rod of the same material and he has asked whether or not the skin structure of glass differs from the structure under the surface.

Clark[23] furnishes one answer to this when he states that glass approaches the condition of certain substances where the surface has been found to be built up from crystal grains with a high degree of preferred orientation, while in the interior the grains are disposed entirely at random. Thus it would seem that strength tests, in order to be comparable, should be performed on specimens with some form of standardized cross-section and of controlled thermal history.

XII. Reflectance and Color

The properties of reflectance and color have justly received current attention. The progress of the Tests Committee of the Porcelain Enamel Institute is common knowledge.

It is estimated by the Better Vision Institute[40] that 85% of man's impressions are received through the eyes and that the energy consumed varies with the ease of visibility. Abundant, well-diffused light has the effect of magnifying objects and making moving objects appear to move more slowly. These are important considerations in construction involving the surroundings of production lines. Various colors from white to black grade down in reflectance from 85 to 2%.

Matthes[6] states that a color matcher is essential in controlling minimum and maximum weight and thus the enamel color. Aydelott and Pfeiffer[1] grade parts for color by comparing them to standard panels under a special light. Rogers[41] describes the Westinghouse photoelectric-color matcher; it is particularly good for matching whites, the most difficult color problem. Differences hardly discernible to the eye are readily shown by the color matcher.

The new G. E. color analyzer has also been described.[42,43] It is essentially a monochromator, photoelectric photometer and means for recording their respective indications. In less than three minutes after the start of a test, the operator removes a chart showing exactly how much of each wave-length of light is reflected or transmitted by the sample.

XIII. Building Construction and Weathering Tests

The use of enamel in building construction promises to be wide-spread. Such broadening of use brings with it new problems. Desirable properties must be established by proper test methods.

Typical of architects who have declared themselves, Lescher[44] sees extended use of enamel in the building field and he envisions enamels on frameless steel-wall units. In the use[45] of porcelain enamel for large-scale and diversified construction, some of the properties that must pass careful tests include (1) methods of paneling and attachment, (2) allowance for expansion and contraction, (3) elimination of sweating, and (4) provision for heat, cold, and sound insulation. To these should be added corrosion resistance. For enamels to be exposed to the elements, the keen desire to produce light-absorbing mat shades and pleasing pastel shades should not be allowed to overshadow adequate weathering properties.

These are all fundamental principles that must be perfected if enamel is to be accepted, as hoped for. Insofar as is compatible with "rugged individualism," the various companies involved would do well do make common cause of many of their problems.

As an accelerated weathering test, Ammon[46] describes a cylindrical container inside of which light, heat, cold, and water spray are applied, in cycles, for long periods of time. Paints fail badly but vitreous enamels do not. It is possible that with some stiffening action, such as dust (abrasive) and solutions of selected p_H values, various enamels could be compared. The same reasoning applies to the use of a "complex machine"[17] developed by the Bureau of Standards in coöperation with the A.G.A. laboratories to check corrosion of finishes.

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[37] G. H. Spencer-Strong, "Some Experiments in the Development of a Sand-Abrasion Machine," *Jour. Amer. Ceram. Soc.*, **19** [4] 112–15 (1936).

[38] News Item, "Pyrex Enters Field of Pots and Pans with Top-of-Stove Ware," *Ceram. Ind.*, **26** [2] 99–100 (1936); *Ceram. Abs.*, **15** [5] 148 (1936).

[39] J. S. Gregorious, "Mechanical Strength of Glass and Its Resistance to Thermal Shock," *Bull. Amer. Ceram. Soc.*, **14** [8] 272–73 (1935).

[40] News Item, "Increased Light Values with White Paint," *Ceram. Ind.*, **25** [6] 352 (1935).

[41] A. W. Rogers, "Matching Ceramic Colors with the Electric Eye," *ibid.*, **24** [3] 170–172 (1935).

[42] News Item, "New Color Analyzer Records on Chart," *ibid.*, **26** [1] 51 (1936).

[43] News Item, "New Products," *Ceram. Age*, **27** [1] 267 (1936).

[44] F. M. Lescher, "An Architect Looks at Glass and Enamel," *Ceram. Ind.*, **25** [4] 189 (1935).

[45] News Article, "Demonstrate Functionalism of Enamel in Architecture," *ibid.*, **25** [6] 329–32 (1935).

[46] M. G. Ammon, "Accelerated Weathering Tests on Porcelain Enamel," *Enamelist*, **12** [9] 8–10 (1935); *Ceram. Abs.*, **14** [9] 209 (1935).

XIV. The X-Ray

It is probable that the ultimate value of the X-ray as a research tool is not yet clearly understood, but progress with it has been so rapid and so striking that recent developments must not be overlooked.

According to Clark,[23] the X-ray is answering the question as to "what is glass." Molecular arrangements that are not entirely random are found, especially at the skin or surface. Warren and Loring[47] found no evidence of compounds in soda-lime glass but they noted that the primary factor in determining the stability of a silicate is the tetrahedral surrounding of each silicon by four oxygens.

In air hygiene, the X-ray is finding use[48] in the investigation of employees' health at the beginning of employment and periodically thereafter. In the growing list of states[49,50] where dust hazard legislation is being passed, insurance rates are mounting, but these are susceptible to revision downward in cases where the hazard is shown to be nonexistent. Here, the potential value of the X-ray should not be overlooked.

XV. Air Hygiene

The question of contamination of plant air is one that must undoubtedly come up for immediate attention. Many states are falling in line with occupational disease legislation. It is not altogether a question of plant conditions, for in many cases the most modern dust-preventive measures may already have been taken. The reduction of discriminatory insurance rates must also be considered. This may be done (1) by furnishing proof that hazardous conditions do not exist, (2) by subjecting prospective employees to test, or (3) testing all employees periodically.

Dust-hazard laws[49] went into effect in New York State on September 1, 1935. Enameled-ironware manufacturing is subjected to one of the highest insurance rates. Rates may be lowered on proof that the hazard is nonexistent. North Carolina[51] has included occupational diseases as well as accidents under occupational disabilities. Insurance rates have leaped[50] in California as a result of silicosis laws followed by a broad statute of limitations ruling.

One new pottery plant[48] has "licked the dust problem" by careful provision for dust elimination. Periodic X-ray examinations of employees, furthermore, are made, filed, and indexed. Plant morale has been raised, and a higher type of operative attracted to the plant. Taken altogether, a better attitude has been created toward a hazard that while existent has been greatly magnified, particularly in the last year.

One of the first objectives of the recently organized Air Hygiene Foundation,[52] which is working in coöperation with Mellon Institute of Industrial Research with H. B. Meller as managing director, will be to furnish accurate scientific information to lawmakers who are preparing to enact safety measures.

This Foundation also may advise industrial plants as to the best preventive measures and advance tests calculated to show the degree of hazard existing.

XVI. Conclusion

The problems considered in this report have not been discussed in any fancied order of importance. The topics have been arranged to follow, in a general way, the enamel processing cycle and subsequent evaluation, depending on the use for which it is intended.

The field covered is broad. Some features could not properly be considered as being within the province of any tests committee as now constituted. It is believed, however, that most of them should receive some degree of consideration.

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[47] B. E. Warren and A. D. Loring, "X-Ray Diffraction Study of the Structure of Soda-Silica Glass," *Jour. Amer. Ceram. Soc.*, **18** [9] 269–76 (1935).

[48] News Article, "Licking the Dust Problem," *Ceram. Ind.*, **25** [5] 263–66 (1935).

[49] News Item, "Workmen's Compensation Insurance Rates for Occupational Dust Hazard Disease Classifications in New York," *Ceram. Age*, **26** [3] 102 (1935).

[50] News Item, "Silicosis Causes Leap in California Rates on Workmen's Compensation Insurance," *Ceram. Ind.*, **25** [6] 326 (1935).

[51] News Item, "Trade and Financial Notes," *Ceram. Age*, **26** [6] 236 (1935).

[52] News Item, "Air Hygiene Foundation Working on Silicosis," *Ceram. Ind.*, **26** [2] 107 (1936); *Bull. Amer. Ceram. Soc.*, **15** [1] 30 (1936).

(B) THE NEED FOR STANDARD TESTS FOR ENAMELS FROM THE VIEWPOINT OF THE USER OF ENAMELS

By W. H. Pfeiffer

Abstract

The present status of testing methods for enamels and enameling and the need for standard methods are discussed. In some cases satisfactory methods are available, but they need standardization in order to be universally useful. In other cases new test methods are necessary to provide for the proper study and development of enamels.

I. Introduction

In considering the adoption of standard tests there are two viewpoints that may be taken. One is that a test should be as nearly perfect as present knowledge can make it before it is adopted tentatively, with the expectation that general use and further knowledge will bring out its weaknesses which can be corrected before it is adopted as a standard. The other is that any test that has been developed or is being used which appears to be satisfactory should be adopted in the rough as a tentative standard, with the expectation that it will be criticized severely by those who try to use it and that modifications and improvements will naturally result until it is satisfactory.

The standardization of enamel tests has not progressed by being attacked from the first viewpoint and it is time to try it from the second viewpoint to see if something can be done. In the attempt to have perfection at the start, the test that was adopted as standard for the fineness of wet-milled enamel has practically no value to the industry. No one can criticize the precision and correctness of taking a sample for screen test that contains 100 grams of frit, but the industry finds it unnecessary and refuses to accept it. A test that is not used is worthless. On the other hand, acid-resisting enamels have come into wide use and thousands of tests are being made each year. Shall we wait until the perfect test is produced before we consent to try one tentatively, and meanwhile let chaos reign and have as many tests as there are testers? Certainly the manufacturers of enamel frit and enamelware know by this time what is required of their products and have found tests which indicate to them necessary standards. There is no quicker way to arrive at satisfactory standard tests than to adopt any reasonable test as tentative, suffer the criticism, and make adjustments as rapidly as possible.

It is in the light of the second viewpoint that the following discussion of the need for standard tests is written.

II. Abrasion Resistance

Lack of a suitable method for determining the abrasion or scratch resistance of enamels has been a hindrance to the enameling industry in several ways. It has retarded the development of lower firing cover coats as it has generally been found that abrasion resistance and refractoriness go hand in hand. It has caused considerable concern in the application of enamels to new uses owing to the uncertainty of meeting new conditions. There has been no recognized improvement in the abrasion resistance of enamels since there has been no means of study. Furthermore it is not known how the variations possible in the enameling process affect the abrasion resistance of the enamels now in use.

One difficulty in the development of a suitable method, for sheet-iron enamels at least, is that the entire resistance to abrasion is contained in the surface glaze on account of the different character of the underlying portion. For this reason it would appear that test means which attempt to distinguish the degree of failure after a standard treatment would be unsuitable and that a test means of varying severity is necessary so that the point at which failure first occurs may be determined.

The National Bureau of Standards[1] has undertaken the development of a standard test as part of its immediate or early program and it is to be hoped that it will find a satisfactory solution.

III. Acid Resistance

Gautsch[2] has given a comprehensive treatise of tests for acid resistance up to the year 1932 and has made the essential observation that ". . . it is evident that one set of specifications for testing all types of vitreous enamelware is inadequate. The uses to which various ware are to be subjected governs the nature of the test."

Since 1932 the use of acid-resisting enamels has become general in all branches of the enameling industry and practically all enamelers have used some sort of test. During this period each manufacturer has fairly well determined the degree of acid resistance necessary for his product and a test which indicates when this degree has been attained. With this background it should be possible to set up workable classifications for acid resistance that are necessary for the industry and rather simple, practical tests for measurement.

The National Bureau of Standards[1] has undertaken to develop methods of testing enamels for acid resistance. The confusion and doubt that have existed in the absence of standard tests should encourage everyone to support this work.

IV. Chipping

Although considerable attention has been given to chipping tests by many investigators, nothing so far developed seems to be very satisfactory. Probably the reason is that the chipping characteristics of an enamel depend upon several of its physical properties and the require-

[1] E. C. Crittenden, "Advisory Committee on Enamels Suggests New Research at National Bureau of Standards," *Bull. Amer. Ceram. Soc.*, **14** [1] 47 (1935).

[2] Murray C. Gautsch, "Acid Resistance of Enamelware," *ibid.*, **11** [5] 134–38 (1932).

ments vary considerably with the use to which an enamel is put. A uniformly satisfactory test would be invaluable to the industry but seems as improbable of attainment as the use of a single test to judge the quality of steel, whether for use in bridges, office buildings, or railroad rails.

Enamels are governed by the laws of mechanics the same as other materials and they should be given the same consideration. Chipping may result from any of the types of stress described by the laws of mechanics, notably compression, tension, shear, fatigue (?), impact, etc. These stresses are either residual in the enameled piece as it comes from the furnace, owing to differential expansion, or are imposed later by assembly to other pieces and by externally applied forces from handling or accident. Resistance to chipping is determined by the physical properties of the enamel. The residual stresses are governed by thermal expansion and elasticity. The imposed stresses are resisted by elasticity, strengths and, in the case of heat shock, thermal expansion.

Considering the variety of forces that can act to cause failure and the number of physical properties involved, it is little wonder that attempts to devise tests that reproduce or simulate have not been very fruitful. High chipping resistance can be obtained only by the specification of enamel of the proper physical properties for the job to be done. There is no short cut.

V. Color

In making and selecting new white enamels and opacifiers and colored enamels and color oxides, there are no satisfactory means available for color analysis of the product. The development of more opaque white enamels, the renewed interest in tin-oxide substitutes, and the new interest in architectural enamels increases the need for accurate color measurement and selection.

VI. Consistency of Enamel Slips

There is nothing more troublesome in enamel processing than the behavior of milled enamel and nothing more impossible to predict than what a new enamel slip will do when put into use. That this is true is attested to by the many studies that have been made and reported,[3] particularly concerning ground-coat enamel.

At the present time the adaption of an enamel to a particular application to secure the best results and the maintenance of the enamel at its best condition depend upon the experience and skill of the enameler. He can aim only at the best conditions since he has no means of measuring them and can compensate only for seasonal changes as trouble arises. To overcome this condition, a test method is needed to evaluate the consistency of enamel when it is working properly in a given operation so that this consistency may be readily maintained by the proper adjustments for changing conditions and so that the behavior of new enamels may be predicted and speedily adjusted.

Harrison[4] has pointed out the fundamental properties of milled enamels and a means for measuring them, but this method by its nature is limited to research laboratories. Irwin[3] has discussed the other methods which have been used and pointed out their advantages and disadvantages. Perhaps one of these methods would be satisfactory or serve as a starting point.

VII. Crazing or Cracking

Cracking of the fired enamel, during or after cooling and from residual or imposed stresses, is a tensile or shear failure of the enamel and falls into the discussion offered under the heading of "Chipping" (section IV). It was believed for some time that the cross-bend test was a measure of the resistance to cracking, but this test has been questioned as confusing two properties indiscriminately. (See "Cross-Bend," section VIII.)

VIII. Cross-Bend

Interest in the cross-bend test seems to have fallen by the wayside in the time since it was recommended for adoption.[5] Gautsch[6] has shown that the results of the cross-bend measurements depend primarily on the thermal expansion of the enamel and questions whether it reveals anything of the resistance of the enamel to cracking. It would seem necessary to make thermal expansion, tensile strength, and cross-bend tests on a series of enamels of varying properties in order to evaluate the test, after which it should be recognized in its true light or discontinued.

IX. Density of Milled Enamel

It is customary to measure the density (often erroneously called specific gravity) of milled enamel as an indication of its water content. The Enamel Division Standards Committees of 1927–28[7] and 1929[8] discussed the specification of the sample bottle, scales, weights and counterbalances, etc., which were to be used, but all this detail seems to be unnecessary. Common practice has been to weigh an ordinary glass graduated cylinder that has been filled to the 50- or 100-cc. mark and subtract the weight of the cylinder. If greater accuracy is required, the size and shape of the sample bottle could be specified but this does not appear to be necessary.

X. Enameling Iron Sag Resistance

Although enamelers have never seemed to concern themselves much with tests of the sheet metal which they use, there is one characteristic which can readily be tested and which should interest all enamelers, namely, sag resistance.

Butts[9] was the first to point out the inherent sag resistance of enameling iron sheets and a method for testing. In principle, when a section of enameling iron sheet is sup-

[3] J. T. Irwin, "Consistency Testing Methods," *Enamelist*, **11** [12] 10 (1934); *Ceram. Abs.*, **14** [1] 4 (1935).

[4] (*a*) W. N. Harrison, "Controlling the Consistency of Enamel Slips," *Bur. Stand. Tech. Paper*, **22** [356] 91 (1927).
(*b*) W. N. Harrison, "Vitreous Enamel Slips and Their Control," *Jour. Amer. Ceram. Soc.*, **10** [12] 970 (1927).

[5] "Report of Enamel Division Standards Comm., 1930," *Bull. Amer. Ceram. Soc.*, **9** [9] 269 (1930).

[6] Murray C. Gautsch, "Relation of Coefficient of Expansion to Cross-Bending Strength of Sheet-Steel Enamels," *Jour. Amer. Ceram. Soc.*, **15** [1] 8–12 (1932).

[7] "Report of Enamel Division Standards Comm., 1927–28," *Bull. Amer. Ceram. Soc.*, **11** [12] 347 (1928).

[8] "Report of Enamel Division Standards Comm., 1929," *ibid.*, **12** [9] 273 (1929).

[9] C. H. Butts, "Checking Sag-Resisting Properties of Enameling Iron," *Better Enameling*, **3** [6] 21 (1932); *Ceram. Abs.*, **11** [12] 607 (1932).

ported at two points and heated, it will sag down a distance depending upon its inherent characteristics as well as the conditions to which it is subjected. The importance of this to the problem of warping should be obvious but is discussed by Aydelott and Pfeiffer.[10]

Although the apparatus described by Butts may not be the most suitable, the principle involved is fundamental. Since it is comparatively easy to set standard conditions for this test, it should be done before a number of investigators turn up with an equal number of test conditions.

XI. Fineness of Wet-Milled Enamel

A standard method for testing the fineness of wet-milled enamel was adopted in 1930[5] but it is so impractical that it has been refused by the entire industry except for a few research laboratories. In the interest of precision, the size of sample was specified to be such as to contain 100 grams of frit but this precision is unnecessary to sampling and causes unnecessary difficulties.

Spencer-Strong[11] has indicated that the important consideration is to maintain uniform conditions of testing once the proper limits for a given plant have been established. It is true that each plant must work out its own milling fineness and the information gained in one plant is of little value to another except in a general way. It is also true that for each class of enamels most plants use approximately the same mill additions, the density of the frits is about the same, and the variations that occur from these causes are minor to the differences required by shop practice. To gain acceptance in the industry, the standard test should be revised or a second one adopted to provide for a suitable specified volume sample to conform to what the industry is going to do anyway.

The report on the standard method[5] recognized by footnote that new screens may vary in accuracy and change through wear and corrosion. Aydelott and Pfeiffer[10] and Spencer-Strong[11] have noted additional variation due to plugging of the screen openings by frit particles and have recommended periodic calibration of the screens in service against a standard screen. The original accuracy of the test screens is of little importance as long as they are calibrated against a standard. Provision should be made in the standard method for this consideration as it is of the utmost importance and far outshadows the variations included in sampling due to variations in mill additions.

XII. Fired Enamel Thickness

Rusher[12] has described an electric gage for measuring the thickness of fired enamel which can be used on any flat surface regardless of size without destroying the enameled piece. An alternative method is the use of the micrometer caliper in its limited scope.

The constant introduction of larger and more difficult shapes to be enameled calls for a more critical examination of the processing and the finished product. The control of enamel application by the average weight per unit area was, and still is, satisfactory for small pieces of simple design, but the larger and more complicated pieces demand a method that can be used to examine the essential areas individually for the control of enamel application and for the rejection of those pieces whose enamel thickness makes them unsafe.

XIII. Furnace Atmosphere

It has been proved beyond contradiction that a proper furnace atmosphere is necessary to the successful firing of porcelain enamels, and apparently satisfactory methods have been developed to measure this highly necessary condition.

Investigators[13,14] have shown the effect of firing enamels in the presence of various gases. In short, the presence of oxygen or iron oxide is necessary to the development of adherence to the metal; sulfur gases cause a scumming of the enamel surface; water-vapor causes copperheading, blistering, ground-coat boiling, and pitting; carbon monoxide and dioxide in excess cause blistering; and partially burned hydrocarbons cause blistering and copperheading. The importance of this list of defects is obvious to enamelers. Although the furnace atmosphere is not the only cause for these defects, the part which the furnace atmosphere plays in everyday industrial processing will not be known until reliable methods of analysis are available and used.

The investigators[13] have indicated the methods of analysis and control used in their experimental work, but particularly to be noted is the work of Ebright, McIntyre, and Irwin,[14] who developed a method of analysis for the ordinary variations encountered and applied it to use on industrial furnaces producing commercial ware. This method employs a train of gas-absorption tubes for the determination of moisture and acid gases and a standard Orsat gas-analyzing apparatus for carbon monoxide, carbon dioxide, and oxygen. No provision is made for fluorine, sulfur gases, hydrogen, or stray gases such as chlorine. In considering a standard method for furnace atmosphere analysis, this method will bear critical examination as a starting point.

XIV. Gloss

Little or no work has been reported on the measurement

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[10] E. C. Aydelott and W. H. Pfeiffer, "Enamel Shop Control," *Better Enameling*, **6** [3] 12 (1935); *Ceram. Abs.*, **14** [6] 133 (1935).

[11] G. H. Spencer-Strong, "Importance of Screen Care in Enamel Fineness Control," *Amer. Enameler*, **8** [8] 3 (1935); *Ceram. Abs.*, **15** [5] 145 (1936).

[12] M. A. Rusher, "Enamel Thickness Gauge," *Bull. Amer. Ceram. Soc.*, **14** [11] 365 (1935).

[13] (*a*) R. D. Cooke, "Effect of Furnace Atmosphere on Firing of Enamel," *Jour. Amer. Ceram. Soc.*, **7** [4] 277 (1924).

(*b*) E. E. Geisinger and K. Berlinghof, "Effect of Furnace Gases upon Glass Enamels," *ibid.*, **13** [2] 126 (1930).

(*c*) A. I. Andrews and E. A. Hertzell, "Progress Report on the Effect of Furnace Gases on the Quality of Enamels," *ibid.*, **13** [8] 522 (1930).

(*d*) H. E. Ebright and G. H. McIntyre, "Effects of Water-Vapor on Porcelain Enamel During Firing," *Enamelist*, **10** [6] 11 (1933); *Ceram. Abs.*, **12** [8] 293 (1933).

(*e*) Wesley G. Martin, "Enameled Defects Prevented by Firing in Inert Gas Atmosphere," *Ceram. Ind.*, **25** [1] 20 (1935); *Ceram. Abs.*, **14** [9] 210 (1935).

[14] H. E. Ebright, G. H. McIntyre, and J. T. Irwin, "Study of Furnace Atmospheres and Temperature Gradients and Their Effect on Porcelain Enameling," *Jour. Amer. Ceram. Soc.*, **18** [10] 297–302 (1935).

of the gloss of enamels. High gloss has been considered an almost exclusive attribute of porcelain enamel in the nonmetallic finish field in the past, but the advances in other finishes have eliminated this advantage. Consequently enamelers are compelled to give more attention to the consideration of gloss. It is commonly known from observation that under high gloss orange peel shows up more distinctly and that under low gloss color differences are more clearly defined to the eye. This observation focuses attention on the growing interest in architectural enamels which employ both low and high gloss surfaces in combination with a variety of colors. These considerations certainly justify an interest in a means of measuring this important property so that it may be evaluated and controlled and the proper standards set. Fortunately the National Bureau of Standards[1] has undertaken this work.

XV. Ground-Coat Adherence to Metal

For many years the sharp bending of an enameled piece or the free swing of a hammer on to it so that the nature of the fracture could be noted were the tests used to determine the quality of the adherence of the ground coat to the metal. Even today a long-handled ball peen hammer can be used to advantage. Ebright, Clawson, and Irwin[15] have shown an improvement on the hammer method by driving an approximately semispherical depression in the enameled metal by means of impact on a die. Kinzie and Miller[16] accomplish the same thing by means of a die in an arbor press but employing a slow and uniform pressure. Neither of these methods is quantitative, yet they are both valuable in that they set up standard reproducible conditions that permit a uniform grading not possible with the ball peen hammer method. Since it appears that many tests for adherence will be made before a quantitative test is developed, one of the above methods or a modification should be considered for adoption tentatively to stimulate interest and study.

XVI. Physical Properties

The National Bureau of Standards[1] has undertaken the study of the important physical properties of enamels and already this work throws some light on a perplexing problem. Those who have concerned themselves with the use of highly opaque cover coats[17] are aware that trouble from blistering, pinholing, and sagging has generally increased with an increase in opacity. In a progress report,[18] the Bureau states, "results so far obtained indicate that sheet-iron ground-coat frits, containing little if any suspended matter, are viscous. . . . Cover-coat frits, containing suspended matter to produce opacity, apparently are not viscous but are non-Newtonian fluids, as might be expected." While this early report does not show us the way out of our difficulties, it indicates something of the nature of our problem.

The importance of a knowledge of the strengths, elasticity, and thermal expansion of enamels has already been discussed under the headings of "Chipping" (section IV) and "Crazing or Cracking" (section VII). The importance of a knowledge of the viscosity (or plasticity) and surface tension of enamels at and around the firing temperature to the minimizing of blistering, pinholing, sagging, and hairlining is obvious.

It is comparatively easy to point out the importance of standard methods for measuring the physical properties of enamels, but these tests are admittedly the most difficult of development of all with which we have to deal. It is time, however, that their importance be generally recognized so that they may be given constructive thought and the ground work laid for their reception. We are fortunate that the Bureau has undertaken the task of the preliminary work.

XVII. Reflectance

The National Bureau of Standards[1] is engaged in developing a standard test method for measuring the reflectance of enamels. It would seem unnecessary to concern ourselves with this problem but rather to offer our full cooperation and support to the Bureau, inasmuch as it is generally recognized that a standard test method is indispensable to the comparison of enamels.

XVIII. Softening Point and Fusion

The importance of the measurement of the fusion properties and the softening point of enamels is obvious from the number of tests that have been devised and the wide use to which they have been put.

Sweo[19] has pointed out the requirements of tests for fusion properties and Harrison and Sweo[20] have compared the five principal methods of determining fusion properties and softening points. These authors have summed up the situation quite thoroughly and their reports indicate that the various tests can be divided into two classes.

In one class are the tests which measure the softening temperature or softening point. This represents a single, definite property of enamel which is useful, as is the measurement of any property of a material in evaluating the characteristics of the enamel.

In the other class are the tests which measure the "fusion-flow" properties, with or without an estimate of the softening point. This means that the enamel is made to soften and flow and the characteristics are judged by the amount of flow and the way in which it flows as compared to the temperatures used. In other words these tests are an estimate of the combined effect of softening point, viscosity, and surface tension of the enamel. Their justification lies in the fact that the action simulates that of the enamel during firing. They can in no way be considered

[15] H. E. Ebright, C. D. Clawson, and J. T. Irwin, "Some Sheet-Iron Ground-Coat Reboil and Bond Studies Using Several Enameling Stocks," *Jour. Amer. Ceram. Soc.*, **16** [7] 305 (1933).

[16] C. J. Kinzie and J. B. Miller, "Method for Testing Adherence of Ground Coats to Metal," *Bull. Amer. Ceram. Soc.*, **14** [11] 371–73 (1935).

[17] F. R. Porter and G. L. Bryant, "One Cover-Coat Enamel Finishes," *ibid.*, **14** [11] 367–69 (1935).

[18] Anon., "Consistency of Enamels at Firing Temperatures," *Nat. Bur. Stand. Tech. News Bull.*, No. 223, p. 116 (Nov., 1935).

[19] B. J. Sweo, "Fusion Properties," *Bull. Amer. Ceram. Soc.*, **11** [5] 133 (1932).

[20] W. N. Harrison and B. J. Sweo, "Some Fusion Properties of Ground-Coat Enamels as Influenced by Composition," *Bur. Stand. Jour. Research*, **10** [2] 189 (1933).

to replace the softening-point tests but must be considered separately and as additional information.

Since the fusion-flow tests indicate a combination of properties, the results are difficult to interpret and can easily be misleading. The only reliable procedure is to measure the viscosity and surface tension as the individual quantities that they are, but until these tests are worked out the fusion-flow tests may be useful.

XIX. Tearing

The present interest of the industry in the production of ware with the application of a single cover coat increases the importance of the resistance of enamels to tearing. Observation has shown that tearing may be of more than one type or have more than one cause. For a given milled enamel, tearing may result from too heavy application or from metal movement before or during firing even with very light application. Porter and Holscher[21] have reported the testing of tearing by bending dried enameled strips in the Lindemann-Danielson cross-bending machine and then firing, but they did not report any study of the effect of enamel thickness.

Whether the resistance to tearing is dependent upon some single fundamental property of the enamel ("film strength" of the dried enamel, for instance) has not been proved. Consequently it would seem logical that means for testing resistance to tearing must be devised for use until such time when a better knowledge of the subject has been gained.

XX. Temperature Gradients in Furnaces

So little work has been done on the measurement of the temperature gradients in the furnaces in use today that it is impossible to predict the full importance of the correlation of such measurements to the results achieved. It is well known that there are characteristic differences in the results of the box furnace and the continuous furnace and even in two furnaces of the same type. There has been little attempt to translate these differences into measurements. Furthermore there are fundamental differences in the requirements of the various types of enamelware being produced. Few of these requirements are known in terms of rate of heating. They are met by general experience and trial and error.

There are two phases of the problem to be considered. First is the rate of heating and cooling that depends on the furnace design, construction, and inherent characteristics. Second is the uniformity of the temperature over a cross-section of the firing chamber that depends upon the furnace regulation and control as well as the design and construction. Each one has its own importance and can be considered separately.

(1) Rate of Heating and Cooling

In studying a case of copperheading in a continuous furnace, Ebright, McIntyre, and Irwin[14] used a method that has been successful in the metallurgical field as applied to the annealing of heavy forgings in continuous furnaces. The method is to weld a long thermocouple to a piece of ware and pass it through the furnace in the regular manner, taking temperature readings at regular intervals. The venting of the firing zone did not change the analysis of the atmosphere but stopped the copperheading. The temperature measurements showed the effective change to be that of an increased rate of heating of the ware, roughly from 55°F per foot of travel to 70°F per foot.

The importance in the case of copperheading is obvious, but what is the importance to tearing, hairlining, gloss, ground-coat boiling, etc.? Before conclusions can be drawn, many measurements must be made on many furnaces, but they must be made by the same method and under the same conditions to be comparable.

(2) Uniformity of Temperature

The matter of the heat distribution in a furnace has always been a matter for concern and it is well recognized that the firing cycle is a compromise between the coldest spot and the hottest spot in a given furnace. Uniformity as influenced by furnace design and construction could be studied by the thermocouple method and permanent corrective changes made, but uniformity depends so vitally on furnace loading, regulation, and control that constant routine testing is necessary, and obviously a simpler and quicker method is needed. Aydelott and Pfeiffer[10] have reported a method which has been effective on continuous furnaces, and there is no reason why its use could not be extended to box furnaces. Along with ware in the regular firing operation, enameling iron strips are passed through the furnace on a suitable fixture so that they will sag. The amount of sagging is proportional to the heat treatment and thus the effective heating in the various parts of the firing chamber is indicated. Certain precautions are necessary in this method and it would have to be adapted to the various firing conditions in use, but it is the only simple practical test reported in the literature.

XXI. Thermal Shock

Landrum[22] and Kinzie[23] have described methods for testing enamels for resistance to thermal shock. Attempts have been made to use these tests to predict the resistance of enamel to chipping when used on any kind of ware, but evidently these attempts were not successful since they do not appear to be reported in the literature. Resistance to thermal shock is an important characteristic of cooking ware and heavy ware that is used in industrial manufacturing processes. A standard method of testing would seem necessary to evaluate enamels properly for these industries.

XXII. Weight of Enamel Application by Dipping

The Enamel Division Standards Committee 1927–28[7] seems to be the last one to consider the dipping-weight test. They recognized that an enameling iron test panel was not satisfactory as no two pieces are the same and they change with use. They also recognized that it was not necessary that the weight of enamel picked up by the test

[21] F. R. Porter and H. H. Holscher, "Use of Finely Milled Enamel Slips," *Jour. Amer. Ceram. Soc.*, **18** [2] 39–42 (1935).

[22] R. D. Landrum, "Comparison of Ten White Enamels for Sheet Steel," *Trans. Amer. Ceram Soc.*, **14**, 489 (1912).

[23] C. J. Kinzie, "Apparatus for Testing Enamels and Glazes for Resistance to Crazing under Thermal Shock," *Jour. Amer. Ceram. Soc.*, **15** [2] 112–15 (1932).

piece be the same as that picked up by the pickled ware being dipped, and they recommended a panel on which ground coat had been applied and fired. This kind of test panel may or may not be satisfactory but it deserves careful consideration because some sort of easily reproducible test piece is essential.

This Committee considered a test piece of 2 sq. ft. unfavorably and preferred one 12 inches square or 17 inches square (289 sq. in.). If several sizes are desirable, it would seem preferable not to use fractional square feet but to make panels 12 in. x 12 in. and 12. in. x 24 in. optional and require that the enamel be drained down the 12-inch dimension. This Committee also considered the angle of repose for the test piece during draining and seemed to prefer that it be set at 21° 31′ with the vertical. This would be the first step against the general adoption of a standard test throughout the industry for it would require special equipment at each dip tank that is not necessary, inasmuch as vertical draining as judged by the operator is widely used and seems to be entirely satisfactory.

It should not be difficult to arrive at a standard method for this test and there is certainly sufficient justification for its standardization considering its wide use.

XXIII. Conclusion

It is recognized that this list of tests is incomplete and that there are others that are important and deserve attention. These were selected because they seemed to be the most important or the easiest of fulfillment. Thermal expansion was not mentioned because there are satisfactory methods in general use by those who need them.

FRIGIDAIRE DIVISION
GENERAL MOTORS CORPORATION
DAYTON, OHIO

(C) DESIRABLE SERVICE TESTS FROM VIEWPOINT OF A COMMERCIAL ENAMEL LABORATORY

BY G. H. SPENCER-STRONG

ABSTRACT

The desirability of the standardization of simulated service tests now in use in the enamel industry and the need for the development of new tests are discussed. Service tests in use in allied industries are commented on.

I. General Discussion

The development of satisfactory simulated service tests is of considerable importance to the enamel industry and of especial importance to the commercial enamel laboratories. Inasmuch as enamel frits must be developed with ultimate service requirements in view, the commercial laboratories, dealing as they must with all types of enamels, in the past few years have played a major rôle in service-test development.

The requirements of a suitable service test call for an accurate simulation of service requirements with a maximum of speed, simplicity, and economy. In many cases, more than one test will be required, because most enamels in service represent a compromise in properties. The results frequently must be reported in relative terms rather than in precise numerical form.

Because of the nature of porcelain enamel, that is, the fact that it is a thin layer of glass containing a large number of bubbles adhering to comparatively thin sheet metal, enamel service testing gives rise to problems not encountered in the testing of such similar products as paints, glass, or sheet metal. These factors have made the results of the tests uncertain, their statement in mathematical form difficult, and have resulted in the development of many comparative tests. There is a considerable sentiment in the industry which favors the development of more scientific testing with its subsequent precise statement of results. The general trend, at the present time, is undoubtedly toward such tests. Before this goal is reached, a great deal of work and standardization of methods will be required. It will be necessary for the various commercial laboratories to work out tentative test methods, which should be correlated by some central agency. Some of this work is now in progress through the coöperation of the Committee on Standardization of Tests of the Technical Research Section of the Educational Bureau of the Porcelain Enamel Institute, and the National Bureau of Standards.

It must be recognized that the standardization of tests which are improperly developed or which are too technical may do more harm than good. Many of our present tests require expert technical knowledge for their proper interpretation. In the hands of persons unskilled in or unsympathetic with the art, the results of their use might react unfavorably to the industry. For this reason, there has been a sentiment against the widespread standardization and publication of tests. The fact remains, however, that there is a rapidly growing tendency on the part of consumer's laboratories to test our product, and if we can not give them proper service tests, they will try to develop the tests themselves with results which may be disastrous to the industry.

It would appear advisable that the industry coöperate as much as possible with these laboratories.

II. Summary of Tests

Andrews[1] has discussed approximately fourteen types of tests which might be used to obtain information as to the serviceability of enamels. Of these types of tests, eight are in common use in the commercial laboratories, al-

[1] A. I. Andrews, Enamels, pp. 325–72. Twin City Printing Co., Urbana, Ill., 1935.

though many of the others may be taken up from time to time as parts of special investigations. The tests are in various stages of development; some are practically standard, others have reached a state where standardization has become desirable from the standpoint of all concerned, while still other tests are not satisfactorily developed either because of lack of interest or because they depend upon so many variable factors that their ultimate development is difficult.

The present status of the various types of service tests as to their state of development, possibilities, desirability, and comparison of work done on similar tests in other fields, may be best reviewed by considering the various types of service tests individually.

(1) Alkali-Resistance Test

The test is old and fairly well standardized, consisting of placing the ware in a sodium-hydroxide solution at or near the boiling point. The time of immersion and strength of solution vary between laboratories, ranging from 1 to 5% NaOH and from $^1/_2$ to 24 hours.

(2) Acid Resistance

This test is being studied by the Committee on Standardization of Tests of the Porcelain Enamel Institute and the National Bureau of Standards, with a view to standardizing it.

Another type of acid-resistance test, which has not received a great deal of attention in the industry is the actual solubility of the enamels themselves in cooking acids. The attention of health authorities is now being called to these tests. For example, all cooking vessels for public use in London County, England, must be so tested by allowing a 0.5% solution of citric acid to remain in the vessel for 24 hours. The solution is then drawn off, evaporated, the residue ignited, and the dissolved solids determined.[2] An American testing laboratory follows a similar test, boiling tomatoes for 24 hours in the vessel, drying, igniting, and analyzing the ash for poisonous substances.

(3) Deflection

This test is generally used as revised in 1930. No further work has been reported since that time.

(4) Impact

Impact tests are in need of a thorough review and standardization. Two general types of tests are in use: the falling ball[3] and the pendulum type.[4] The results are so dependent upon other factors, such as metal, metal gage, and enamel application,[5] that results from various laboratories are not comparable. Many enamelers have adopted tests in which a blow is given or a stain is made, greatly in excess of the strength of enamel and metal, as a rapid test for adherence.[6]

(5) Abrasion

Considerable work has been done on abrasion, but the results have not been entirely satisfactory because of the lack of a suitable method of measurement. Owing to the bubble structure, the beauty of an enamel is destroyed when the surface layer has been removed. Thus, although the protective qualities of the enamel are still as good as ever, the lack of gloss and tendency to trap dirt impairs the usefulness of the product. Several investigators have recommended loss of gloss as a suitable method for measuring surface abrasion. These investigators have used the Ingersoll glarimeter as a measuring instrument.[7(a)] The use of this instrument on enamels of differing opacity is somewhat questionable, owing to inherent defects in its design. Other investigators[8] have used a loss-in-weight test, the defect in this method being the fact that the abrasion is usually carried through the surface skin. It is felt that a satisfactory method of gloss measurement may go a long way toward solving the abrasion problem as there are many methods available for abrading the surface,[9] if a satisfactory method of measurement is available.

Closely akin to the problem of abrasion is the problem of suitable cleaners for porcelain enamels. The commercial laboratories are continually being asked to test these cleaners and often find so-called cleaners which would make excellent mediums for an abrasion test. While the testing of these products is not fundamentally an enameling problem, the complaints which enamelers may receive as a result of their use are enameling problems.

(6) Hardness

Closely akin to abrasion resistance is the problem of hardness. Interest in hardness testing has increased recently and most of the laboratories have done considerable work on it but no outstanding successes have been reported. The Moh scratch hardness test, utilizing a set of standard minerals, and the weighted point method have been chiefly used. The former method is not entirely satisfactory, because enamels lie between 4 and 6 on the

[2] J. H. Coste and D. C. Garrett, "Acid-Resistance Specification for Enameled Hollow Ware," *Analyst*, **60** [709] 215–19 (1935); *Ceram. Abs.*, **14** [9] 210 (1935).

[3] C. J. Kinzie, "Physical Tests for Vitreous Enamels: I, Determining Physical Properties," *Jour. Amer. Ceram. Soc.*, **12** [3] 188–92 (1929).

[4] R. H. Türk, "Comparison of Results Obtained with Impact Machine," *ibid.*, **13** [11] 887–93 (1930).

[5] (*a*) E. H. Shands, H. G. Wolfram, and R. H. Türk, "Factors Causing Variation of Results in Tests for Physical Properties of Enamels," *ibid.*, **15** [8] 438–43 (1932).

(*b*) G. H. McIntyre, J. T. Irwin, and M. G. Ammon, "Reliability of Cross-Bend, Impact, and Reflectivity Data from Various Sizes of Test Pieces," *ibid.*, **16** [7] 338–41 (1933).

[6] C. J. Kinzie and J. B. Miller, "Method for Testing Adherence of Ground Coats to Metal," *Bull. Amer. Ceram. Soc.*, **14** [11] 371–73 (1935).

[7] (*a*) Paul Sherrick, "Use of Ingersoll Glarimeter in Testing Resistance of Ceramic Glazes to Abrasion," *Ceram. Age*, **12** [3] 101–103 (1929); *Ceram. Abs.*, **8** [7] 511 (1929).

(*b*) A. C. Harrison, "Preliminary Study of Resistance to Abrasion of Ceramic Glazes, Its Control and Method of Determination," *Jour. Amer. Ceram. Soc.*, **10** [2] 77–89 (1927).

(*c*) G. H. Spencer-Strong, "Some Experiments in the Development of a Sand-Abrasion Machine," *ibid.*, **19** [4] 112–15 (1936).

[8] (*a*) W. J. Scott, "Apparatus for Measuring Abrasive Hardness of Glazes," *ibid.*, **7** [5] 342–46 (1924).

(*b*) Edward Schramm, "Sandblast-Abrasion Test for Glazes," *ibid.*, **12** [5] 356–59 (1929); see also footnote 3.

[9] H. A. Gardner, Physical and Chemical Examination of Paints, Varnishes, Lacquers, and Colors, pp. 222–30. Inst. Paint and Varnish Research, 6th ed.

Moh scale, and therefore are classified with difficulty. The second method gives uncertain and variable results, owing to the collapse of bubbles near the surface and to surface irregularities. In other industries, much work has been done on the hardness problem.

Navias,[10] after investigating the hardness of many ceramic materials, recommends the expansion of the Moh scale to make classification more accurate.

Ridgway, Ballard, and Bailey,[11] after testing electrochemical products by hand-scratching (Moh's method) standard points and plates under constant pressure, diamond points, the Rockwell hardness test, and impact abrasion with a sandblast, also recommend the expansion of the Moh scale.

The standard metal-hardness tests, involving the Brinel test, the Rockwell test, or the Shore scleroscope, fail with enamels because of their physical structure.

Eighteen hardness tests in use in the paint and varnish industries are described by Gardner,[12] but these are based chiefly upon variations of the loaded point method.

The glass industry[13] reports tests involving the use of a conically pointed diamond, a cutting diamond, a cutting wheel under constant load and with uniform velocity, and a hand-drawn cutting wheel.

An indication of the possibilities in the hardness measuring field, is a piezo-electrical method, in which the hardness is calculated from the current induced in a quartz crystal placed under the test specimen by the impact of a steel ball.[14]

There is a possibility that, if the enamel be fused to the exclusion of bubbles, cast in a slab, and suitably annealed, many of the hardness tests in use in other industries might be applicable. An extension of the Moh hardness table, however, should result in a rapid, simple, and economical test method of sufficient accuracy for general use in the enameling industry.

(7) Thermal-Resistance

There has been little work reported on thermal-resistance tests, although most of the laboratories have developed such tests. A heat-shock test described by Landrum[15] in 1912 is still in rather wide use in the testing of hollow ware. Kinzie[16] has reported a test, more elaborate, and more easily controllable, than the Landrum test. The field, especially in the matter of quenching, presents excellent opportunities for investigation.

(8) Weathering

The increased use of enamels for exterior work has brought up the question of weathering. A great deal of work has been done in the paint and varnish industries[17] on accelerated weathering tests and, although nine test instruments are described, it is admitted that the results are not generally comparable with the results of actual weathering. These devices make use of a cycle in which the specimen is irradiated with intense light, made to pass through water sprays, and at times is exposed to low temperatures and gas actions.

Tests by Ammon,[18] using an Atlas Weather-O-Meter, indicated no change in enameled specimens after 297 days, while organic finishes broke down rapidly. Ammon did not report exposing his materials to fumes.

An experiment on the weathering resistance of enamels of all kinds carried on over a period of three years by Karl Türk, Sr., at Ruxton, Maryland, indicates a considerable difference in the weathering resistance of various sheet-steel and cast-iron enamels. Although the protective qualities of the enamels were not impaired, their beauty in some cases was destroyed.

The results of these tests indicate that acids from the air, rather than ultra-violet or infra-red rays from the sunlight, were responsible for the deterioration.

A recent work[19] on smoke prevention indicates that a great deal of the damage from smoke in cities is the result of acids generated during combustion from sulfur in the fuel. The Weather-O-Meter is designed for paints, lacquers, and other organic-type finishes, which are subject to deterioration by sunlight, rather than for vitreous products, as enamels, and it is indicated that it may be necessary to work out an entirely new test before this problem is solved.

PORCELAIN ENAMEL & MANUFACTURING COMPANY
BALTIMORE, MARYLAND

[10] Louis Navias, "Scratch Hardness Tests of Ceramic Materials," *Jour. Amer. Ceram. Soc.*, **12** [2] 69–74 (1929).

[11] R. R. Ridgway, A. H. Ballard, and B. L. Bailey, "Hardness Values for Electrochemical Products," *Trans. Electrochem. Soc.* [Preprint No. 63–27], pp. 261–90 (1933); *Ceram. Abs.*, **12** [10–11] 386 (1933).

[12] H. A. Gardner, *loc. cit.*, pp. 193–211.

[13] A. J. Holland and W. E. S. Turner, "Scratch Hardness of Toughened Plate Glass," *Jour. Soc. Glass Tech.*, **19** [75] 221–30 (1935); *Ceram. Abs.*, **15** [2] 60 (1936).

[14] E. Franke, "Piezo-Electrical Determination of the Hardness of Materials," *Messtechnik*, **10** [12] 211–32 (1934); *Ceram. Abs.*, **14** [8] 200 (1935).

[15] R. D. Landrum, "Comparison of Ten White Enamels for Sheet Steel," *Trans. Amer. Ceram. Soc.*, **14**, 489–509 (1912).

[16] C. J. Kinzie, "Apparatus for Testing Enamels and Glazes for Resistance to Crazing under Thermal Shock," *Jour. Amer. Ceram. Soc.*, **15** [2] 112–15 (1932).

[17] H. A. Gardner, *loc. cit.*, pp. 310–55.

[18] M. G. Ammon, "Accelerated Weathering Tests on Porcelain Enamel," *Enamelist*, **12** [9] 8–10 (1935); *Ceram. Abs.*, **14** [9] 209 (1935).

[19] Henry Obermeyer, Stop That Smoke. Harper's, New York, 1933.

REPORT OF THE FELLOWSHIP COMMITTEE ON EDUCATION*

Last year (1935) marked the fortieth anniversary of the establishment of collegiate training in ceramic technology, and undoubtedly the study of ceramic curricula began before that. College curricula, in all fields, have been subjects for study and debate as long as there have been colleges, and there has never been a period of greater activity of this kind than the present. While change does not necessarily mean improvement, it usually implies a healthy dissatisfaction which has resulted in a critical study followed by an effort to do in a better way that which has been done before.

The consideration of engineering education as a whole, or in part, is necessarily involved with some of the larger problems. An example of the magnitude of the problem of higher education is the fact that, while the population of our country increased 62% between the years 1900 to 1930, yet attendance at institutions of higher education increased over 300%. This enormous increase, together with the social, industrial, and economic changes during that period, have subjected educational machinery to burdens for which it has not been particularly well adapted. Readjustments are constantly being made but not always as speedily and effectively as desirable.

Only about a generation ago, a high-school education was a privilege enjoyed by relatively few. Now the demand is being made of the present Congress that it subsidize the youth of the country for a college education. In Great Britain, only one in every 1000 of the population attends a university; in France, one in 700; in Germany, one in 650; while in the United States, one in 120.

Speaking in a general way, among the problems confronting the universities at the present time, there are three of great importance: (1) the problem of transition from high school to university, (2) the problem of the university curricula, and (3) the transition from the university to industry. The first of these does not concern the work of this Committee. The second and the third, however, I present briefly for your consideration.

With regard to the curricula, we do not feel that we can add anything of importance to what has appeared in the publications of the Society or has been discussed in the meetings. We wish, however, to direct the attention of those not familiar with the activities of the Society for the Promotion of Engineering Education and some technical societies to the voluminous and valuable studies made under their direction. The details of the practical application of these principles to specific curricula in any school will be governed by such practical consideration as finances, the teaching personnel, the facilities available in coöperating departments, the educational policies, and the objectives of the institution.

The curricula of our older ceramic departments are the development of nearly a half century of experience by men of competence in their special fields in association with men of like experience and ability in related engineering lines. Therefore, while we admit the existence of faults, we do not believe that they are other than those common to all branches of engineering education, primarily due to the rapidly changing conditions of our national life. As proof of this statement, we would submit for consideration the record of this Society as displayed in its activities and publications and the contributions to ceramic knowledge and achievements of its members who, in increasing numbers, are graduates of ceramic schools.

Approved Engineering Curriculum

The survey of engineering education carried on by the Society previously referred to furnishes a great deal of valuable material, which, however, cannot be discussed in detail in this report. We shall epitomize briefly some of the opinions expressed by 534 experienced teachers in 115 institutions, 6269 graduates, and 855 prominent members of engineering societies. They believe that a satisfactory engineering curriculum should be characterized by (1) moderate diversity of curricula but tending away from specialization; (2) dominance of scientific and broadly technical content; (3) inclusion of a well-identified core of required matter in common; (4) inclusion, at all stages, of subjects of purely cultural value; (5) due emphasis (though not predominant) on the economic aspects of engineering and on its concern with administration and management; (6) coherence of arrangement and coördination of related subjects; and (7) thoroughness, rather than completeness, of detail.

It is not surprising that a great many manufacturers desire engineering graduates with highly specialized training to fit particular needs. Under present conditions, however, we rarely can foresee the exact place any student will take in industry. Without the knowledge of the particular service a man will be expected to render after graduation, it will be difficult to give him the proper specialized training, and his opportunity for a position for which he is specially trained will be largely fortuitous.

Fortunately, however, while some manufacturers insist upon their need for four-year graduates with highly specialized training, the majority opinion is opposed to such a system of education. Educators and industrial leaders alike generally agree that a four-year college training should be of the broad fundamental type and that the breadth of the students' education should be still further increased by the inclusion of a considerable amount of purely cultural work. This is considered essential if he is to avoid that narrow outlook upon life which so often is associated with highly specialized work.

E. B. Roberts of the Westinghouse Company, in an address before the Society for the Promotion of Engineering Education at Atlanta in 1935, stated that the engineer is so often so completely preoccupied with his own technique that he neglects all other interests and values. His tendency often is to measure people and situations in the objective terms of his own technique, so that he fails to gage the reactions of people to everyday situations and problems. The experience of this Company has shown them that the engineer has not been led to develop that sense of values that is not objectively measurable but which is absolutely essential to his success. His very success through objective methods has limited his outlook and restricted his usefulness in the modern manufacturing organization.

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, March, 1936.

Since it is pretty generally agreed that a four-year curriculum is too crowded to permit specialization, we are coming more and more to the conclusion that if specialization is necessary, it must come in graduate work. This means, of course, that industrial organizations should not and can not expect specialization of four-year graduates in the particular field in which the individual manufacturer is interested. Such specialization must require at least a five-year curriculum, or the industries themselves must provide that additional specialized training as a transition from the general fundamental training obtained in college to the highly specialized requirements of industry. It is generally agreed that this is as it should be, for the student who specializes during his four-year college course at the sacrifice of fundamental training has an extremely limited field of usefulness which necessarily limits his possibilities for future growth.

The situation with respect to graduate work would be improved if all students were given a broad fundamental training as undergraduates. Then, if industry would assure the schools that a certain number of men with graduate work would be employed, the universities would be delighted to do whatever might be necessary to train these men for the particular service required.

Some of the larger companies have definitely recognized this need by providing training courses for the purpose of acquainting the new graduate with specialized processes and products. The training not only increases the man's immediate value but greatly improves his possibilities for future development in the company. Naturally, it is an advantage both to the student and to the manufacturer to accomplish this transition in as short a time as possible.

In general, we have need for a broad fundamental and cultural four-year college curriculum which must be increased to at least five years if specialization is desired; and we have need of closer coöperation between educational institutions and industry for the promotion of specialization in graduate work and the transition of students with broad fundamental training to the highly specialized requirements of industry.

Many changes are taking place constantly in educational processes in general and in engineering education in particular. We must not lose sight of the fact that much is being done toward general improvement in education and that while improvement in our ceramic curricula is highly important, it still is only a small part of the general problem of education.

The members of this Committee are as follows: C. E. Bales, A. V. Bleininger, A. F. Greaves-Walker, F. A. Harvey, A. V. Henry, M. E. Holmes, T. N. McVay, A. S. Watts, and C. W. Parmelee, *Chairman*.

—C. W. PARMELEE, *Chairman*

SUMMER MEETINGS

REFRACTORIES DIVISION, BEDFORD SPRINGS, PA., SEPTEMBER 4 AND 5

Meeting to Draw Operating Men from Steel and Glass Industries

The Refractories Division will hold its Summer Meeting at Bedford Springs Hotel, Friday and Saturday, September 4 and 5. The technical session will be devoted to a discussion of checker brick and regenerators. The program provides for golf and other recreational activities. There will be a full program for the ladies.

The Bedford Springs Hotel, which will serve as host to the Division, is located in Pennsylvania's cool mountains, about one hundred miles east of Pittsburgh. Among its facilities are an excellent eighteen-hole golf course, swimming pool, riding, and badminton and tennis courts.

The meeting is scheduled for the week-end preceding Labor Day, so that those who wish to may extend their vacation by attending the meeting.

Following is an outline of pertinent details of the program:

Thursday, September 3

Plant trips (optional).

Friday, September 4

9:00 A.M. to 12:00 M.: Registration, Bedford Springs Hotel.

12:00 M.: Luncheon.

2:00 P.M.: Technical Session in Auditorium.

General Subject: Checker Brick and Regenerators

Paper by J. D. Keller, Research Engineer, Carnegie Institute of Technology. Subject: "Influence of Material, Shape, and Size of Checker Brick on Regenerator Performance."

Paper by William C. Buell, Jr., Consulting Engineer, Cleveland, Ohio; author of The Open-Hearth Furnace. Subject: "Performance of Checker Brick under Various Operating Conditions." The speaker will discuss abuses in the design of open-hearth regenerators which affect the performance of checker brick.

Discussion: To assure full discussion of both papers and of operating experiences in the steel and glass industries, a number of persons have been invited to prepare discussions.

2:00 P.M.: Ladies Program: Bridge in the Colonnade, prizes.

6:30 P.M.: Clay-Workers Club Reception in Private Dining Room.

7:30 P.M.: Banquet.

9:00 P.M. to 12 MIDNIGHT: Dancing, Ball Room.

Bedford Springs Hotel

Facilities for Reaching Bedford Springs, Pa.

Location

Bedford Springs Hotel is located on a 2500-acre estate, two miles from Bedford, Pa., on the Lincoln Highway (U. S. Route 30); distance east of Pittsburgh, 99 miles; west of Philadelphia, 199 miles.

Transportation Facilities

Railroad: Train service through Altoona, Pa., and Cumberland, Md., connecting with bus line going direct to hotel door. Buses leave Altoona at 7:00 A.M., 10:15 A.M., 1:32 P.M., 4:45 P.M., and 5:00 P.M. (running time about 1:40); leave Cumberland at 7:00 A.M., 10:00 A.M., 1:45 P.M., and 5:30 P.M. (running time about one hour).

Bus: From Pittsburgh or Philadelphia; Great Eastern and Greyhound Lines to Bedford, Pa. Taxi service from Bedford to Bedford Springs.

For further details write the Summer Meeting Program Committee Chairman, W. C. Rueckel, 1424 Koppers Building, Pittsburgh, Pa.

Saturday, September 5

9:00 A.M.: *Men:* Golf Tournament. Prizes for low gross score, kicker's handicap, and high gross score (booby prize).

Ladies: Putting contest, prizes.

12:00 M.: Luncheon.

2:00 P.M.: Golf, swimming, etc.

WHITE WARES DIVISION

Symposium on "Preparation of Whiteware Bodies to Secure Uniformity"

JAMES WILSON HEPPLEWHITE, JR., CHAIRMAN

Hotel Bartlett, Cambridge Springs, Pa., September 18 and 19.

"Development and Control of Whiteware Properties" as discussed in *The Bulletin*, **15** [2] 56 (1936) and **15** [3] 95 (1936).

Selection of raw materials, physical and chemical properties, soluble salts, composition of blunging water, and the working methods to produce ware having the most certain and easily controlled properties will be discussed.

MATERIALS AND EQUIPMENT DIVISION

The Materials and Equipment Division of the American Ceramic Society will hold a joint meeting with the Industrial Minerals Division, American Institute of Mining and Metallurgical Engineers, Friday and Saturday, September 25 and 26, at Pennsylvania State College.

The subject of the symposium for the technical program on Friday afternoon is "Beneficiation of Ceramic Materials by Flotation."

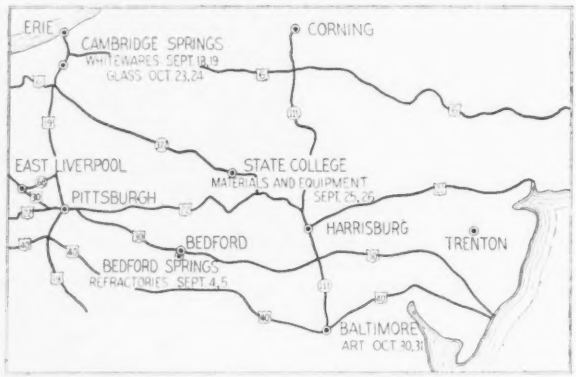
The following are some of the papers which will be presented on this program:

(1) "Raw Material Requirements," by E. H. Fritz, Westinghouse Electric & Mfg. Co., Derry, Pa.

(2) "Milling and Classification of Feldspar," by V. V. Kelsey, Consolidated Feldspar Corp., Trenton, N. J.

(3) "Flotation as a Method of Beneficiating Clays," by M. C. Shaw, The Edward Orton, Jr., Ceramic Foundation, Columbus, Ohio.

(4) "Magnetic Separation," by G. W. Jarman, Jr., and S. G. Frantz, Separations Engineering Corp., New York, N. Y.



MEMBERSHIP STATUS

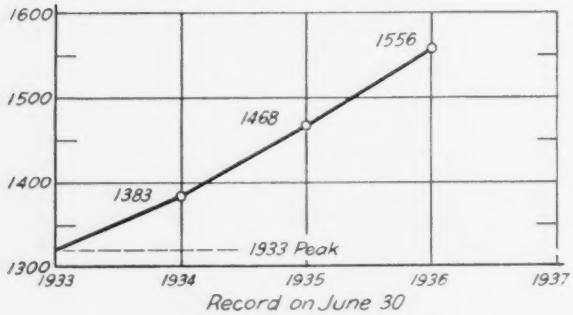
Slowly you are selling space on the good ship Ceramics for a sailing on Progress River. To make this sailing more economical and pleasant, and therefore more profitable to you, more space should be sold.

Here is your three-year record, net, as of June 30.

	1934	1935	1936
Personal Paid	1166	1239	1332
Personal Deferred	58	49	43
Corporations	159	180	181
Subscribers	419	416	495

MEMBERS ARE CLIMBING ONTO GOOD SHIP CERAMICS

Are you helping your friends to get on board thus making more profitable to all this sail down Progress River?



Record on June 30

NEW MEMBERS

Corporation

THE WAYNE LABORATORIES, John J. Shank (voter), 17 East Main St., Waynesboro, Pa.

Student

KEY, JOHN A., University of Washington.

Personal

ALONSO, ANTONIO R., Lopez Landron 40, Santurce, Puerto Rico.

BORKEY, J. HARRY, 805 Otis Bldg., Philadelphia, Pa.; district sales manager, North American Refractories Co.

ERDLE, R. W., 5932 Wentworth Ave., Chicago, Ill., president, Austenal Laboratories, Inc.

EVANS, CHARLES E., 303 S. Cross St., Robinson, Ill.; junior ceramist, W. A. Case & Sons Mfg. Co.

HAZARD, ROWLAND, La Luz, New Mexico; president, La Luz Clay Products Co.

NEFF, VERA ODEYNE, 11312 Hessler Rd., Cleveland, Ohio; ceramic artist.

RITTER, SARA, Ironton Chamber of Commerce, Ironton, Ohio; secretary.

SURFLEET, HAROLD, Kaylene Ltd., Waterloo Rd., London, N. W. 2, England; chemist.

TITUS, H. B., 50 Church St., New York, N. Y.; North American Refractories Co.

VOSS, WALTER C., Room 5-229, Massachusetts Institute of Technology, Cambridge, Mass.; professor of building construction.

Membership Workers' Record

Personal		Corporation	
Alice A. Ayars	1	Office	1
C. E. Bales	1		
Frederick Heath, Jr.	1	**Student**	
M. E. Holmes	2	Hewitt Wilson	1
P. W. Lee	1		
J. M. McKinley	2		
Office	2	**Grand Total**	**12**

ROSTER CHANGES DURING JULY*

Personal

ALBERY, D. F., American Terra Cotta Corp., Crystal Lake, Ill. (Chicago, Ill.)
BENNETT, A. LEE, 2510 Silver Lake Terrace, Los Angeles, Calif. (Glendale, Calif.)
BURLINGAME, H. G., Florence Stove Co., Kankakee, Ill. (Lakewood, Ohio)
LANGENBECK, KARL, 1019 Findley Ave., Zanesville, Ohio. (Washington, D. C.)
LEE, P. WILLIAM, Austenal Lab., Inc., 5932 Wentworth Ave., Chicago, Ill. (Crystal Lake, Ill.)
KERR, W. R., Armstrong Cork Co., Beaver Falls, Pa. (Lancaster, Pa.)
NIJHAWAN, KRISHAN K., c/o L. Sukh Dyal ji, Retired Deputy Inspector of Schools, Santpara St., Lyallpur, Punjab, India. (Jamshedpur, India)
PLANJE, CHRISTIAN W., Gladding, McBean & Co., Lincoln, Calif. (Chicago, Ill.)
RAINE, FRANK F., Box 284, Concord, Calif. (Seattle, Wash.)
RAUGH, JAMES P., General Refractories Co., 1600 Real Estate Trust Bldg., Philadelphia, Pa. (Cleveland, Ohio)
RHODE, IRMA, Spruce Pine, N. C. (Norris, Tenn.)
SCHURECHT, H. G., New York State College of Ceramics, Alfred, N. Y. (Matawan, N. J.)

* Address in parentheses is the old address.

Student†

BERKELHAMER, LOUIS H., Battelle Memorial Institute, 505 King Ave., Columbus, Ohio. (Univ. of Washington)
HEROLD, JOHN F., Gladding, McBean & Co., Los Angeles, Calif. (Ohio State Univ.)
HYDE, COLLIN, A. P. Green Fire Brick Co., Mexico, Mo. (Ohio State Univ.)
LANE, RICHARD O., Macklin Company, Jackson, Mich. (Mass. Inst. of Tech.)
MCLAIN, WILLIAM R., Carnegie-Illinois Steel Corp., 3426 E. 89th St., Dept. 49, Chicago, Ill. (Ohio State Univ.)
OWENS, CHARLES W., JR., Harbison-Walker Refractories Co., Fairfield, Ala. (Univ. of N. C., Raleigh Unit)
ROBERTS, JOHN T., Crane Company, 836 S. Michigan Ave., Chicago, Ill. (Iowa State College)
ROBINSON, HARRY J., Tennessee Enamel & Mfg. Co., Nashville, Tenn. (Ohio State Univ.)
SCHATZ, STUART, Laclede-Christy Clay Products Co., St. Louis, Mo. (New York State School of Ceramics)
SMITH, GRAHAM G., N. Clark & Sons, Alameda, Calif. (Univ. of Washington)

† Graduates in Ceramic Engineering, Class of 1936.

SEIJI KONDO HONORARY MEMBER OF THE SOCIETY

In the July *Bulletin*, page 252, a life sketch of Dr. Rieke was presented. Dr. Rieke and Dr. Kondo were elected to Honorary Membership of the American Ceramic Society by action of the Board of Trustees at the 1936 Annual Meeting. The following life story of Dr. Kondo is presented here.

Seiji Kondo was born January 31, 1883, at Chishaku of Sakura Village in Mie District of Mie Prefecture.

Education

He completed the ordinary primary school course at Sakura Village in March, 1893, the second year course of higher primary school at Komono Village in March, 1895, and the middle school course at Tsu City in March, 1900.

He was graduated from the government "Third High School" in Kioto in July, 1903, and from the Department of Applied Chemistry, Faculty of Engineering, Tokio Imperial University in July, 1906.

On February 23, 1915, he was ordered by the Department of Education to study the manufacturing methods of pottery, glass, and cements in the United States for two years. On May 10, 1915, he arrived at Columbus, Ohio, to study ceramics under the direction of the late General Edward Orton, Jr., as well as to see American ceramic industries. He studied ceramics under Arthur S. Watts and the late assistant professor Carl B. Harrop of the Ohio State University from March 22, 1915, to June 10, 1916. He also studied the cataphoresis of clay suspension and electrical conductivity of plastic clays under Albert V. Bleininger, Ceramic Division, Bureau of Standards, in Pittsburgh, Pa., from January 22 to March 31, 1917. He left Pittsburgh for Tokio on August 2, 1917.

On October 27, 1919, he was granted the degree of

Kogaku-hakushi (Doctor of Engineering) by the Minister of Education, his thesis having been applied to the Tokio Imperial University.

Professional Work

From December, 1906, to December, 1910, Dr. Kondo worked at the Joshikimen plant of the Nippon Brick Mfg. Co.

From December, 1910, to October, 1911, Dr. Kondo was an instructor of ceramic engineering at the Tokio Higher Technical School; on November 1, 1911, he was appointed by the government as professor of ceramics at the school. Since January 1, 1918, he has been examiner at the Patent Bureau; from December, 1919, to October, 1932, lecturer of ceramics at the Tokio Imperial University; since April, 1922, a lecturer of ceramics at the Tôhoku Imperial University; and since February, 1927, a lecturer of potteries at the Waseda University.

From February, 1922, to July, 1930, Dr. Kondo was a member of the government committee of engineering standards. Since April 2, 1929, he has been professor and chairman of the Department of Ceramic Engineering at the Tokio University of Engineering (established by the Government on April 1, 1929). Since March 1, 1934, he has also been a member of the Research Institute of Building Materials of the University.

For many years Dr. Kondo has been on the staff of abstracters for *Ceramic Abstracts*, covering the Japanese ceramic papers. Dr. Kondo resides at 109 Third Street, Den-en-chofu, Omori-ku, Tokio, Japan.

DR. LITTLETON IS GETTING WELL

In response to the inquiries of many friends of J. T. Littleton, Corning, N. Y., as to how and to what extent he was injured and as to how he is progressing, your Editor and Secretary asked his wife to give the facts. Her letter, in part, follows. He will be pleased to receive messages and callers. He is active in mind and spirit, though for the while quite incapacitated physically.

—R.C.P.

R. F. D. Hammondsport, N. Y.
July 24, 1936.

"On April 11, Jess was returning from a lecture at Bethlehem, Pa. About 10:30 A.M., some man tried to pass three trucks in a row. He crowded the factory car in which Jess was riding off the road. As it went over, the back door on his side was wrenched open and he was caught between the ground and top of the car. The pelvis was broken in two places, the fifth and eighth vertebrae were cracked, and the left knee cap was cracked. The broken pelvis cut the rectum.

"When he arrived at the hospital he was in such a state of shock that the doctors did not dare do any repair work. They could only treat him for shock. On April 13 he had a blood transfusion, followed by a fifteen-minute chill. On Thursday he was desperate all day due to gas gangrene that set in about 3:00 or 4:00 A.M. in the right leg between knee and hip. They said it probably came from the torn rectum and a quart of blood that stayed in a day or so. They could not disturb the packing in the rectum the 48 hours he was in shock. The doctor made 21 incisions in the leg, put in drains, irrigated every 15 minutes, gave him 120,000 units of serum in broken doses. About the eleventh hour, he went into another chill but he came out of it. Gas gangrene is 98 or 99% fatal.

"The next day another transfusion and a 25-minute chill. The next day they gave him gas and cleaned up the leg. The surgeon said he had cleaned up gangsters and wharf accidents but he had never had anything to make him lose a meal before. On Saturday and Sunday they were treating him to prevent serum reaction. Monday he nearly passed out from gas and some intestinal paralysis. The consulting surgeon said he must have some quick relief or die, and the attending surgeon said he was too weak to stand any more chills. From the indirect transfusion, instead of a chill he got some normal sleep, so they gave him one each night for three nights.

"The pelvis was set at the end of three and one-half weeks. Then abscesses formed in the rectum and pus and fecal matter seeped out through the bad leg; after four weeks he had another transfusion and a colostomy. At the end of five weeks they began to feed him regular diet to try to build him up. The abscess in the rectum caused pus to collect in spots all through that region; there was pus from the gangrene leg and in a puffed-up place on his neck. They opened the place on the neck, called in a rectum specialist, who took three days to clear up the old fecal matter that had been there weeks, and put in drains. Jess was so weak that they had to work very slowly. They then kept opening places on his hip and back until there were five drains at once in that region. Either then or before they started opening he had two more transfusions. I do not think he weighed more than 100 pounds at this point. He was in terrible pain until the drains were put in. Since then he has been in less pain and is beginning to eat more and show gain. Then the doctor skin-grafted about 2 inches of the 14 or more inches, waited a week or so, and did more. The rest can not be done until he has less pus. They think they can do some more August 1. He still has three drains but they drain less.

"He came by ambulance (June 23, I believe) to the cottage at Willow Point, Keuka Lake, N. Y. He has gained in both strength and weight. When he came it took four of us to get him on his crutches and it was a day's work for him to go 15 feet on them. Now he weighs 140, and with very little help from the nurse gets out of bed and walks about 40 feet alone once a day. Most of the time he spends in a wheel chair or on the bed. We are well pleased with his condition so far. He has to get rid of all pus before they can finish the grafting. Then the rectum has to be fixed up and completely healed before the colostomy can be "redone," and the colon put back in normal channel. The doctor thinks it will be November at least before that is done.

"Although, he is on the road to recovery, he has several minors and one or two major operations ahead of him yet. They think they can do the minors here at the cottage. The majors will be done in Scranton, I think."

HISTORY OF NORTON COMPANY*

The shop pictured on the cover has been referred to as the cradle of the Norton Company. Back in the 1860's it was a pottery shop occupied by the firm of Norton and Hancock, but later the business was conducted by F. B. Norton, who was producing in the early 70's, in an old-fashioned way, a varied line of stoneware of superior quality itemized as pots and pitchers, jugs, and mugs.

During a workmen's noon hour in the fall of 1873, the discussion turned to the manufacture of an "emery" wheel. This was something new. One of the men had seen an emery wheel which had been made by bonding emery with shellac. Another had already attempted to make such a wheel by tamping glue and emery in an iron mold and drying it on the top of a stove. Employee Sven Pulson ventured to state that he could make an emery wheel using a clay bond. Further discussion led to a bet of a can of beer and, after the third attempt, Mr. Norton paid the bet and Mr. Pulson collected.

His first commercial product consisted of two plugs 4 inches long and 1 inch in diameter, sold to the Winslow Skate Company for work on the heels of skates. But Mr. Pulson experienced considerable difficulty in making his first emery-wheel order for two 12- by $2^1/_2$-inch wheels. His $9 a week wages provided him with insufficient capital and there was a lack of interest at first on the part of Mr. Norton.

Pioneering at Ashland, Mass.

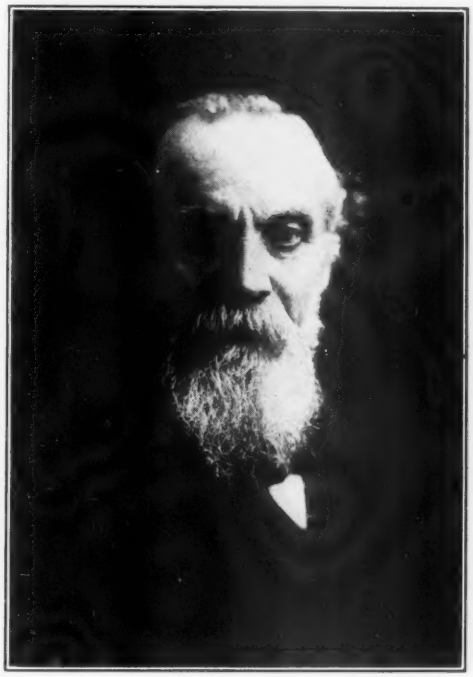
Experimental work with the new type of wheel was carried on later by Mr. Pulson in another shop at Ashland, Mass. It was then that he sent to Taunton, Mass., for his brother-in-law, John Jeppson, an experienced potter, to come and "burn the kiln." The wheels were set on fireclay bats and rings but when the kiln was drawn, it was found that the slip clay used for sealing had run down onto the wheels and glued the fire brick together.

Although there was some activity at that time in the manufacture of artificial grinding wheels, three years passed before the subject was given serious consideration in the little pottery shop. Mr. Norton took out patents in 1876 covering the vitrified emery wheel, but manufacture was started on an extremely small scale. Introduction of the new wheels proved exceedingly difficult. Manufacturers were skeptical, reluctant to try out the new grinding wheels, and for a few years these wheels were made only as a side line to the pottery business and were fired in the same kilns with the stoneware pottery.

John Jeppson Returns to Norton Pottery

Several years after the first emery wheel was made in the Norton shop, the emery-wheel business was still merely a small side line to the stoneware and pottery business. The early historians of the Company, when referring back to the period of 1880, have said that it was a one-man business and John Jeppson was the "one man." He then had secured a permanent job with Mr. Norton and was devoting practically all of his time to making emery wheels, while the rest of the employees were engaged in making pottery.

About this time, the wheel business was given a sales impetus when Walter L. Messer was engaged to further



John Jeppson

the sale of the Norton emery wheel. In 1882 the pottery and emery wheel business at the Norton shop required a bookkeeper, and Charles L. Allen, a young man of promise, was engaged for that job. It was a period when new machinery was being introduced and new vehicles of transportation began to appear. Metals were becoming harder and tougher.

It was natural that these grinding-wheel makers should have business dealings with the Washburn Shops of the Worcester Polytechnic Institute. The wheel men thus came in contact with Milton P. Higgins, founder of the Washburn Shops, and George I. Alden, another educator connected with W. P. I. It is evident that a few men interested in the emery-wheel business and these educators had a vision of the future. They believed that there was a field for the emery wheel.

Norton Emery Wheel Company Incorporated

After long negotiations with Mr. Norton, a purchase of the wheel end of his business was consummated in 1885, and on June 20 of that year the Norton Emery Wheel Company was incorporated with Mr. Higgins as president and Mr. Alden, treasurer. The first board of directors consisted of Milton P. Higgins, George I. Alden, Walter L. Messer, Horace A. Young, and Fred H. Daniels of the Washburn & Moen Company. Charles L. Allen

* For tribute to Charles L. Allen on his completion of fifty years with Norton Company, see *The Bulletin of the American Ceramic Society*, **7** [5] 150 (1928); for election of Aldus C. Higgins to office of President of Norton Company, see *ibid.*, **12** [3] 69 (1933).

became the first general manager, which position he held along with other offices at various periods, including those of treasurer and president until 1933, when he was made chairman of the board of directors. Thus, Mr. Allen is the only man who has served the Company throughout its entire fifty years. This is a record of achievement rarely equaled. The first superintendent of the plant was John Jeppson and he held that position until his death in 1920.

The success of the Norton Company over a period of 50 years and its influence as a factor in the development of the grinding industry was due in no small degree to a fine spirit of coöperation which existed with this group of men who were pioneering in what was to become an important industry.

Growth of Norton Company

In the first year of the emery-wheel company's existence a new factory was built at Barbers Crossing in 1886. It was a two-story structure, 48 by 120 feet, with two kilns. This plant was characterized as large enough to make all the grinding wheels that the world would ever use, and the management had the problem of renting part of the plant for other purposes. The demand for the Norton products, however, soon exceeded the plant capacity and the Company has been enjoying a continuous growth for a half century.

The plant at Barbers Crossing today with its eighty odd buildings and nearly 2,000,000 square feet of floor space is a monument to the integrity and business acumen of a pioneer group of practical dreamers. Today Norton products are known and distributed throughout the world and Norton plants are located in Bauxite, Arkansas; Chippawa and Hamilton, Canada; Wesseling, Germany; La Courneuve, France; Welwyn Garden City, England; and Corsico, Italy.

NOTES AND NEWS

GLASS MEN AT CHEMISTRY UNION

Alexander Silverman, Department of Chemistry, University of Pittsburgh, will attend the meeting of the International Union of Chemistry, Lucerne, Switzerland, August 16 to 22, as a delegate from the American Ceramic Society. He is also a delegate from the National Academy of Sciences and the National Research Council.

J. C. Hostetter, Corning Glass Works, who has been in England attending the Glass Congress, will also attend the meeting of the International Union as a Councilor of the National Research Council, on which he is the representative of the American Ceramic Society.

THE RACKHAM ENGINEERING FOUNDATION AND THE ENGINEERING SOCIETY OF DETROIT

Articles of incorporation of The Rackham Engineering Foundation were filed June 12, 1936. Under the plan adopted, the net income from the Endowment was paid to The Engineering Society of Detroit, Incorporated, April 15, 1936. The purposes of this Society are educational and scientific.

The late Horace H. Rackham accumulated his fortune as a director of the Ford Motor Car Company and as a result of engineering skill applied to the automotive industry. It was the recognition of this fact that prompted the Board of Trustees of the Horace H. Rackham and Mary A. Rackham Fund to create this Endowment.

PITTSBURGH PLATE GLASS COMPANY MULTIPLE FELLOWSHIP AT MELLON INSTITUTE

The Pittsburgh Plate Glass Company has founded a Multiple Industrial Fellowship in Mellon Institute. This Fellowship will study fundamental problems in the various fields covered by the activities of the Pittsburgh Plate Glass Company. This Company has been active in research in its various plants, and the establishment of this Fellowship marks its recognition of the interdependence of technological advances and the value of centralized fundamental research.

Members of the staff appointed to this Fellowship are as follows. Frederick W. Adams, senior incumbent, comes from the Massachusetts Institute of Technology, Chemical Engineering Department, after devoting most of fourteen years to the School of Chemical Engineering Practice. John D. Jenkins of Oregon State College and Ph.D. from the University of Wisconsin, majoring in physical chemistry, comes from the Ditzler Color Company. Harold E. Simpson, Ph.D., Ohio State University, comes from Battelle Memorial Institute. Lee Devol, Marietta College, with several years of industrial experience with the Westinghouse Electric and Manufacturing Company, comes from the University of Pittsburgh where he received his Ph.D. in physics. Kenneth B. McAlpine, Princeton University, Ph.D. in physical chemistry, spent several years with Republic Steel Company before joining the staff of this Fellowship. Phillip W. Crist was graduated this year in physics from Carnegie Institute of Technology.

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Iron Oxides
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Fire Brick
Imported Paris White
Domestic Whiting
Pottery Plaster
Georgia Kaolin

THE POTTERS SUPPLY COMPANY
EAST LIVERPOOL, OHIO

ELECTRO'S SILICON CARBIDE

THREE SUCCESSFUL REFRACTORIES FOR CERAMIC WARE

Non-Gro Tile and Brick	for	Porcelain Enamel Muffles Glass Annealing Lehrs High thermal conductivity at temperatures below 2000° F.
Kellogg AA Batts	for	Biscuit Dinner Ware Bisque and Glost Sanitary Ware One-Fire Hollow Ware Vitrified Porcelain All open settings
Kellogg AA Saggers	for	Porcelain Dinner Ware Electrical Porcelain All high temperature closed settings

We would be pleased to serve you

THE ELECTRO REFRACTORIES & ALLOYS CORPORATION

Andrews Building Buffalo, New York.

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FINEST POTTERY CLAYS

TALC WHITING

H. C. SPINKS CLAY COMPANY

Miners and Shippers of

BALL, SAGGER AND WAD CLAY

NEWPORT, KENTUCKY

August 1, 1936

Mr. Pete Potter
Comfortable Sanitary Pottery Mfg. Co.
Pottsville, Ohio

Dear Pete:

Well, the Olympic trials are over and the All-American athletes are on their way to show the rest of the world what we produce in America. Don't worry! They will make a good record!

For years and years the English Ball clays have been imported into this country, but now the All-American trials in the potteries have definitely proven that such clays as

"JERNIGAN & CHAMPION & CHALLENGER,"

produced right here in Tennessee in the good old U. S. A., are the winners in the race for low losses, high quality and low cost.

Sincerely,

Dick Carothers

General Manager
H. C. SPINKS CLAY COMPANY

RBC:MLN

M&T
Sodium Antimonate

For years M & T Sodium Antimonate has set the standard. The finest opacifier that modern methods can produce, it is always uniform, always pure. Every barrel of M & T Sodium Antimonate is exactly the same, both chemically and physically, as every other barrel.

And, this quality opacifier is more economical. Rejects, due to off colors, become rarities. Whites, whether blue white, cream white or some other hue, do not vary a shade from one year's end to the next where M & T Sodium Antimonate is used.

Our Ceramic Department will gladly help in solving your enameling problems. Homer F. Staley is manager; R. R. Danielson, director of research. Metal & Thermit Corporation, 120 Broadway, New York, N. Y.